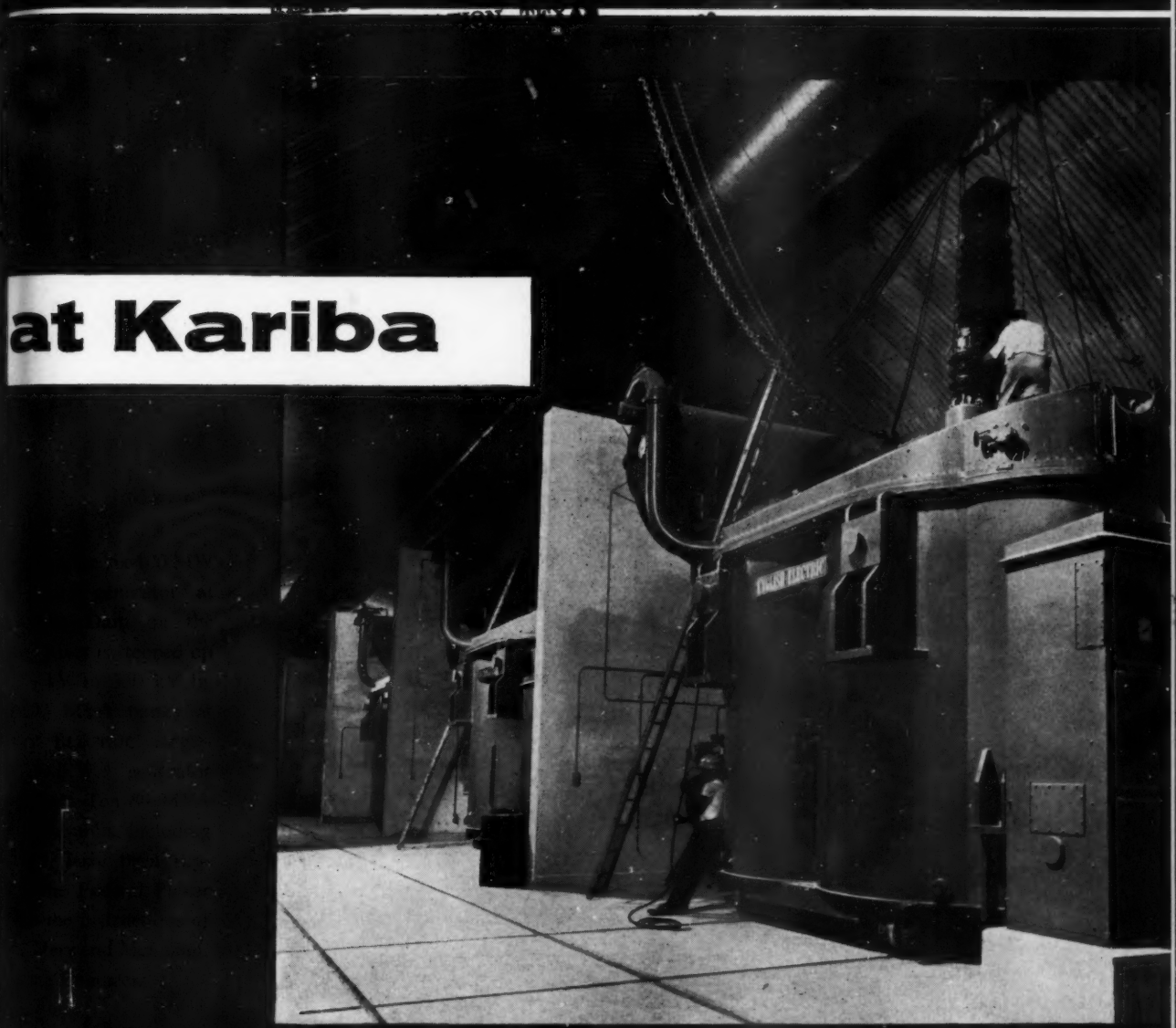
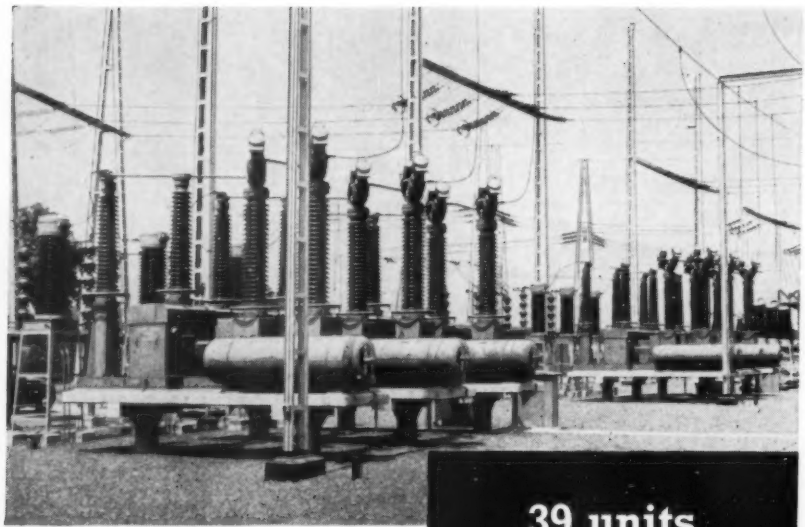


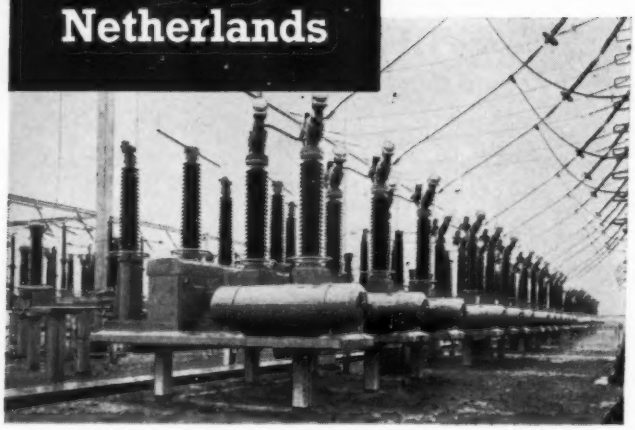
'ENGLISH ELECTRIC'

Buggenum power-station N.V. Provinciale Limburgsche Electriciteits-Maatschappij



39 units in the Netherlands

Centrale Hemweg Gemeentelijk Electriciteitsbedrijf Amsterdam

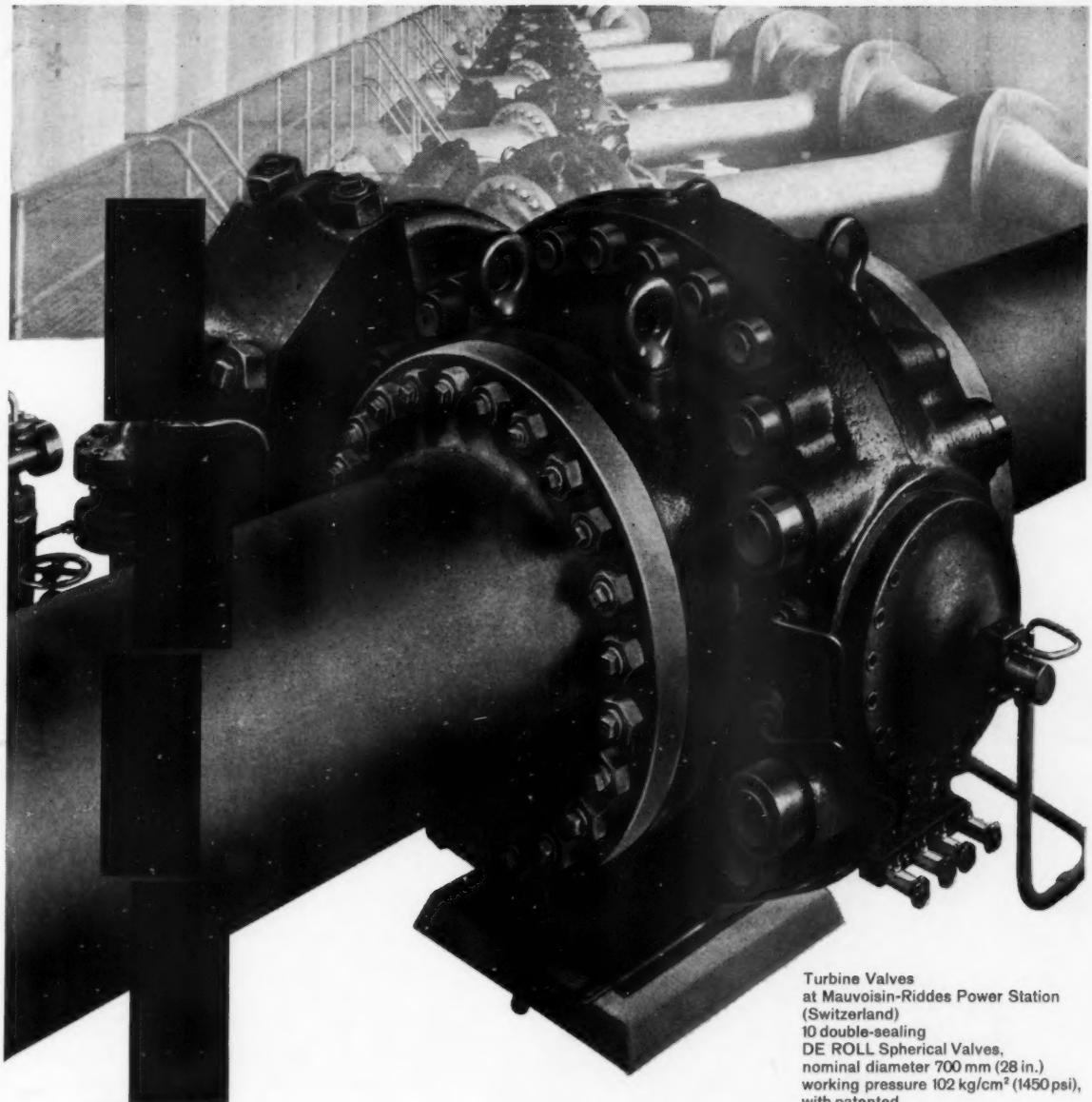


150-kV 7500 MVA TYPE-OB30

AIR-BLAST CIRCUIT-BREAKERS

Reyrolle

A. Reyrolle & Co. Ltd - Hebburn - County Durham - England



Turbine Valves
at Mauvoisin-Riddes Power Station
(Switzerland)
10 double-sealing
DE ROLL Spherical Valves,
nominal diameter 700 mm (28 in.)
working pressure 102 kg/cm² (1450 psi),
with patented
Ring-Piston Servomotor

This is the stone
that makes
the tower
stand or fall.
In a Power Station
it is the **Shut-off Valves**
that provide for the safety
of the entire plant
and thereby
make it stand or fall

320

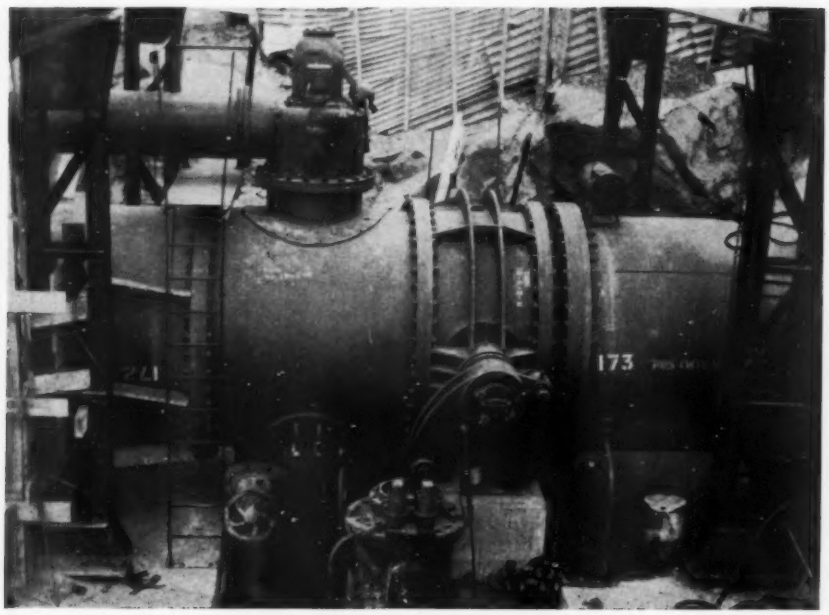
DE ROLL

Shut-off Valves

our speciality

DE ROLL Iron Works, Klus (Switzerland)

Glenfield Valves for Portal Service



BUTTERFLY VALVES

The design and manufacture of large Butterfly valves for portal service in hydro-electric works has for long been a Glenfield specialty.

Illustrated at site is a 6 ft. 6 in. dia. hydraulically operated unit, with a piped-inlet anti-vacuum valve downstream of it; and in cut-out form, a similarly actuated 8 ft. valve with cowled-inlet anti-vacuum valves.

Glenfield

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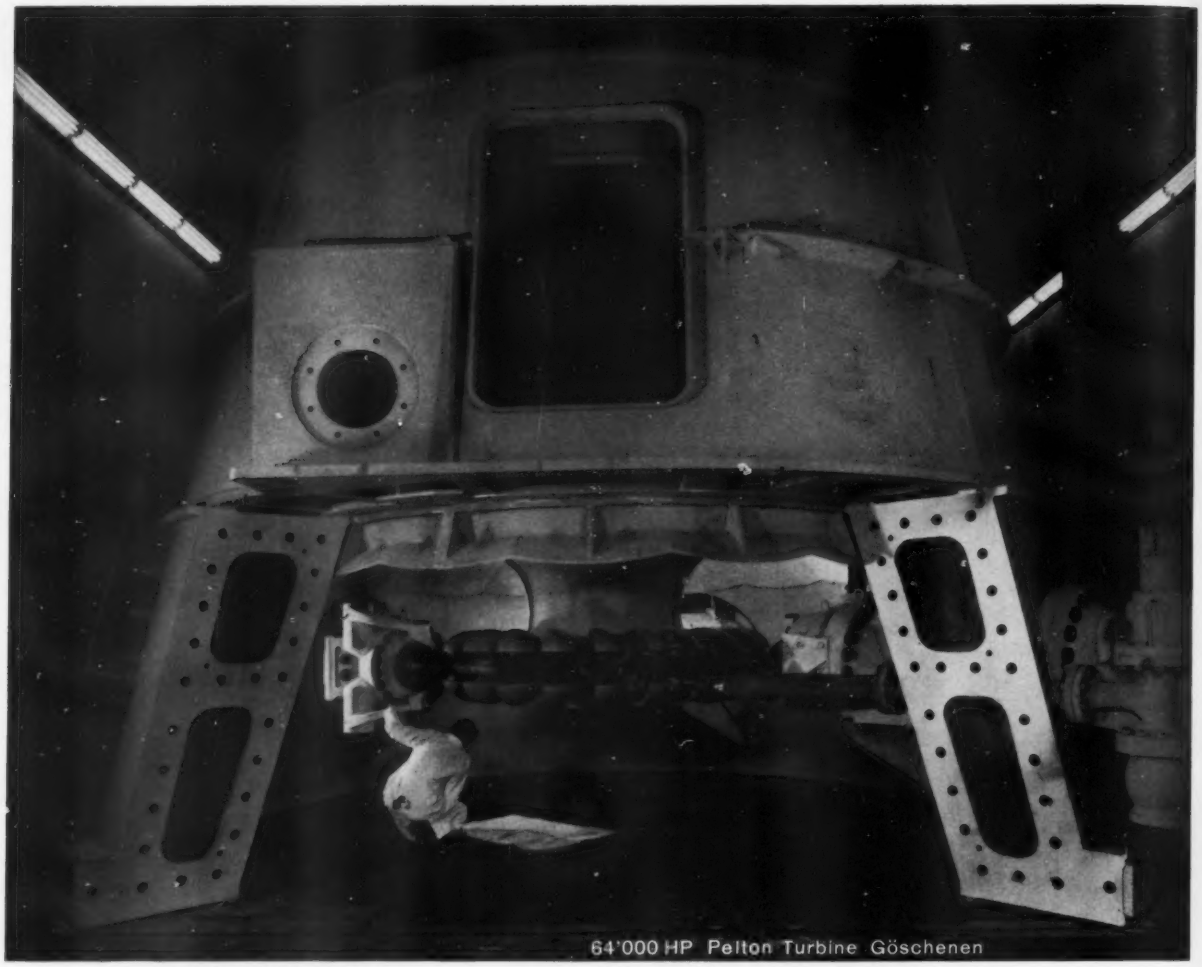

64'000 HP Pelton Turbine Göschenen

TRADITIONAL SWISS ENGINEERING SKILL AND QUALITY

A century of experience in design and construction of waterpower-equipment and constant research in two hydraulic laboratories, one of them especially equipped for cavitation tests, assure the reliablity and efficiency for which Bell turbines are renowned

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Bell builds:
Water Turbines, Spherical straight flow valves, Butterfly valves, Penstocks and supply pipings, Pressure tunnel liners, Partially or fully automatic and remote controlled plants, Power house cranes, Towers for transmission lines, Water control equipment

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Francis Turbines - Guyabo (El Salvador) head 56 m, 24'800 HP - Bärenburg (Switzerland) head 340 m, 85'000 HP (Supply together with Charmilles)
Pelton Turbines - Göschenen (Switzerland) head 698 m, 64'000 HP - Sedrun (Switzerland) head 588 m, 70'000 HP
Kaplan Turbines - Wildegg Brugg (Switzerland) head 15,3 m 34'000 HP - Petäjäskoski (Finnland) head 19 m, 67'600 HP

Bell Engineering Works Ltd.
Kriens/Lucerne (Switzerland)

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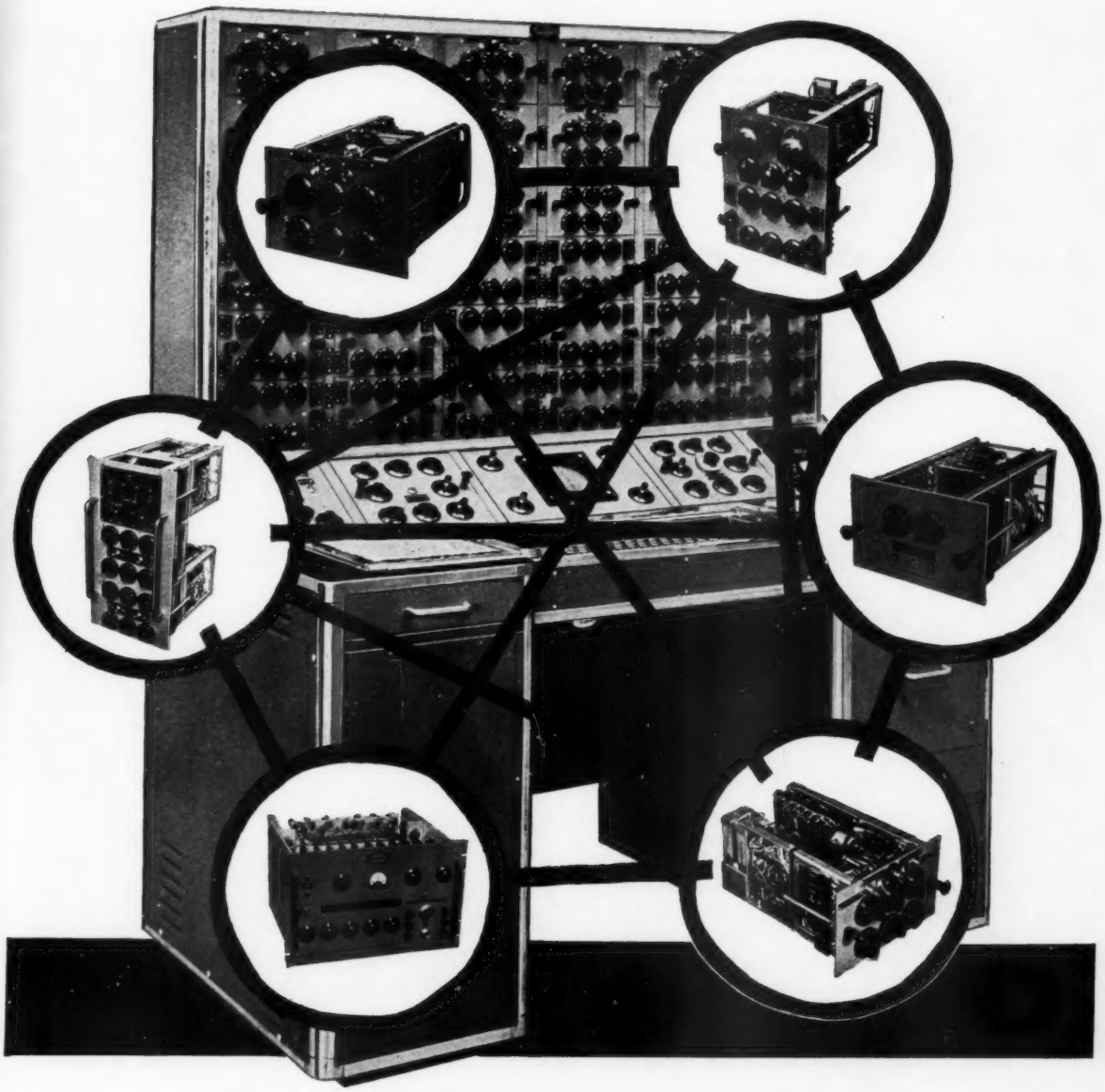

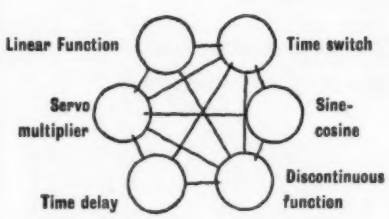

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East India House, 208a Regent Street, London, W.1

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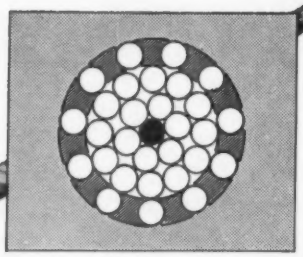

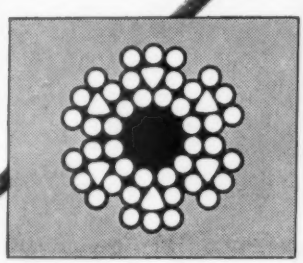

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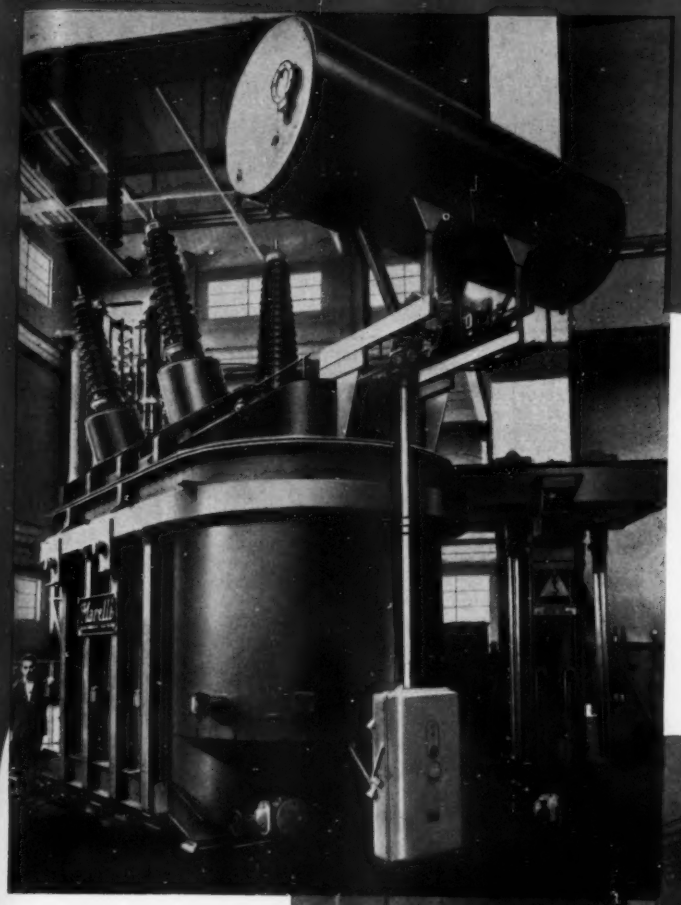
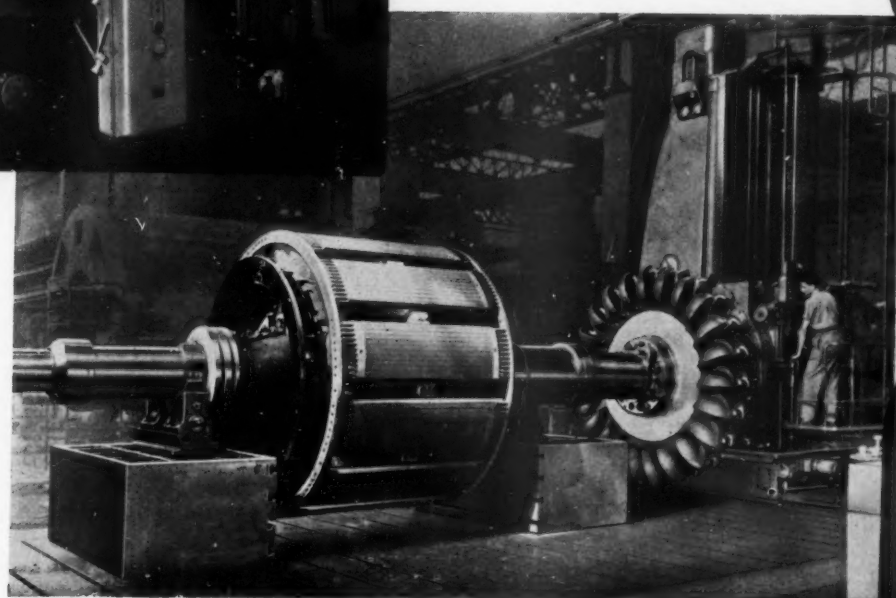


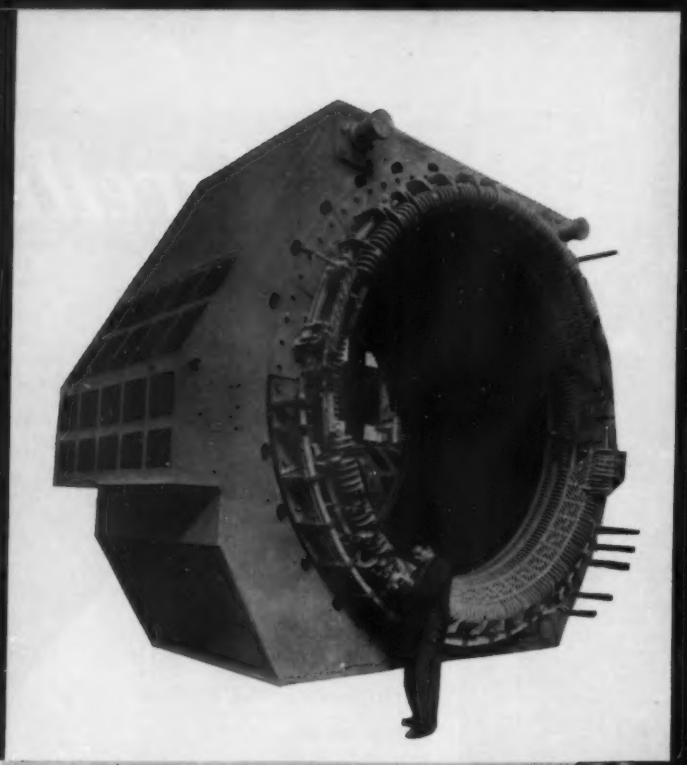
SINGLE PHASE TRANSFORMER for three phase bank 150/150/50 MVA —220/120/10·5 kV—50 cycles 4 units for NIKOLA TESLA substation, Yugoslavia, with under-load tap-changer



Rotor for 25 MVA horizontal type Alternator coupled to Pelton Wheel gauging the coupling bolt holes

2 units manufactured for OESTERREICHISCHE DRAUKRAFTWERKE, Kolbnitz Reisseck power station

ERCOLE MARELLI & C - S.p.A. - MILANO



The stator of the 60MW hydro-alternator at Aura Power Station, Norway.

Wealth o

G.E.C.

power g

Wherever there's water in abundance, there's power potential in abundance too. In Scotland, the G.E.C. is helping to harness this power and has supplied the North of Scotland Hydro-electric Board with three 25MW hydro-alternators and control gear for the automatically controlled Errochty Power Station—the largest in the Tummel-Garry scheme.

Norway is another of the water-lands. Here, deep in the mountainside at the head of the Sunndalsfjord is the Aura Power Station. And here a 60MW hydro-alternator has been installed for the Norwegian State Power Company by the G.E.C. In Tasmania, too, the G.E.C. has recently installed five 25MW hydro-alternators at Tungatinah.

To Scotland . . . to Norway . . . to Tasmania . . . to the water-lands of the world, the G.E.C. sends hydro-electric equipment for generation, control and distribution of power.

h of the water-lands

Three 25MW vertical shaft alternators at Errochty Power Station, Scotland

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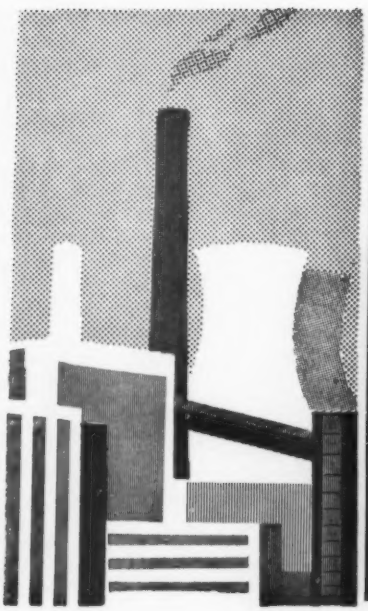

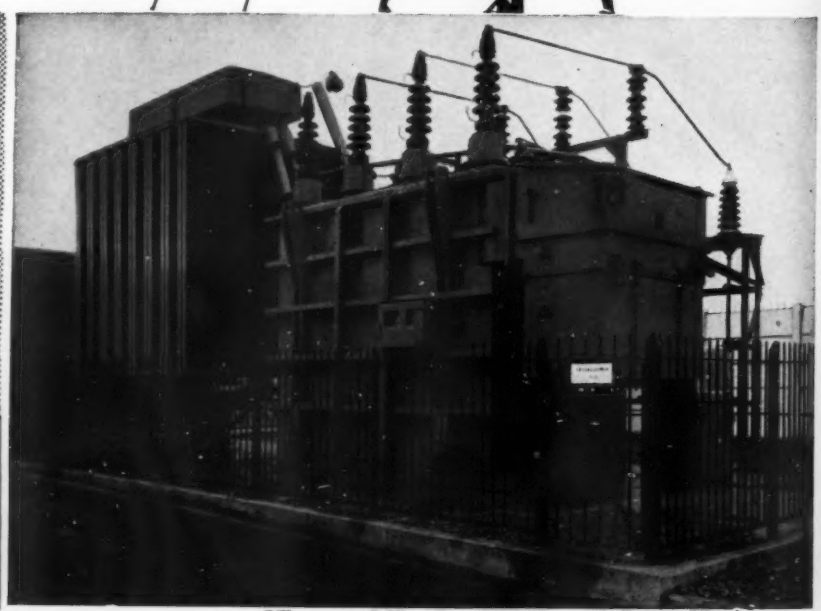

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THORNHILL, DEWSBURY, YORKS., ENGLAND
Tel: Dewsbury 1691-2 Grams: Transforma, Dewsbury

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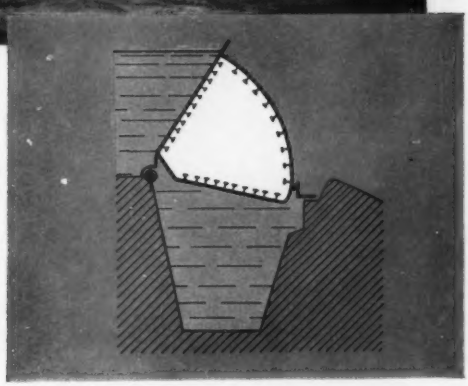
Liapootah Drum Gate in the River Nive, Tasmania.

Gate of 36.6 m clear width and 6.1 m retaining height, acting as a spillway gate of a dam.



Section of a drum gate

M·A·N

HYDRAULIC STRUCTURES

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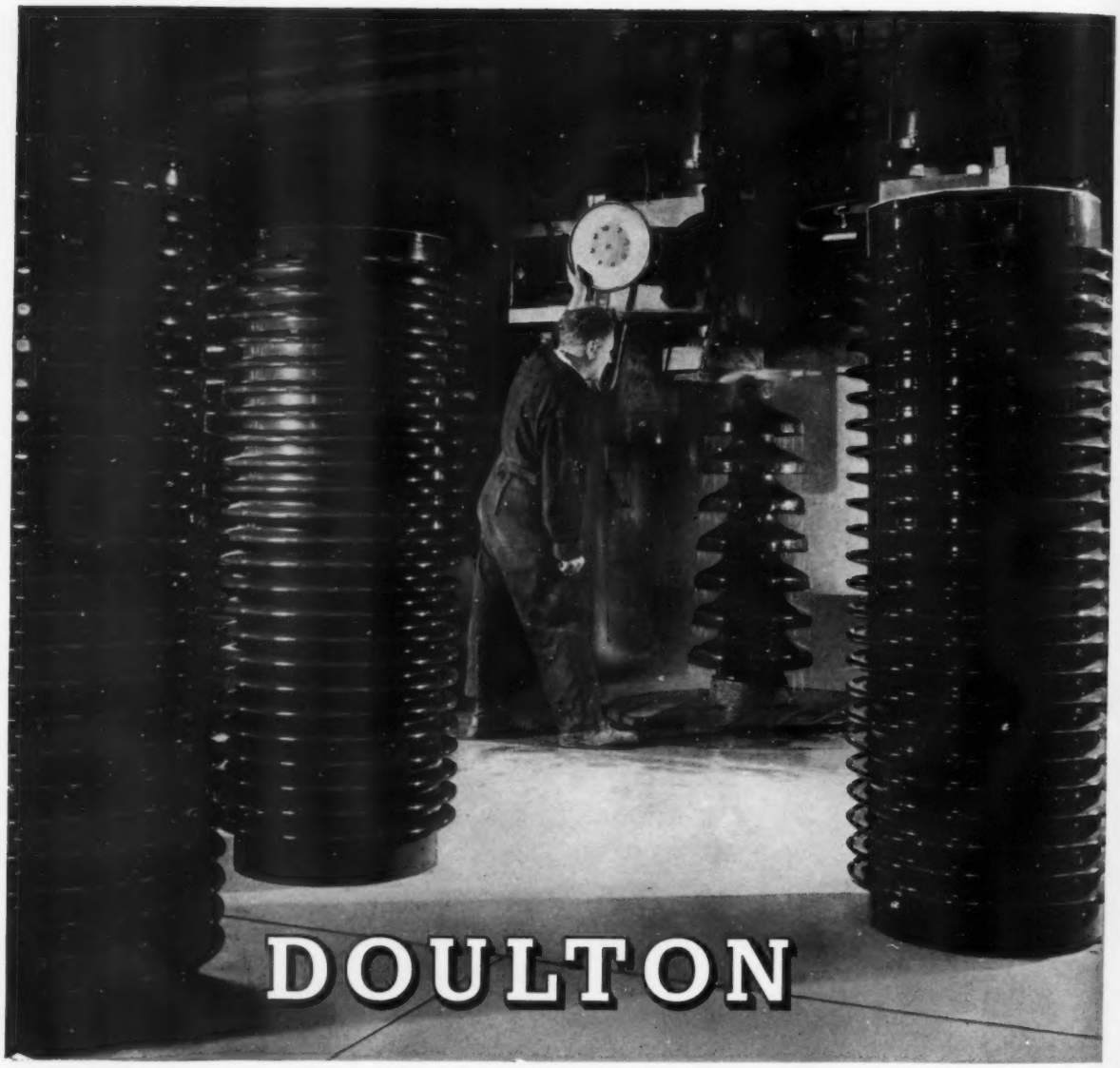

INSULATORS

A 132 kV Porcelain anti-fog cable ceiling end being ground to dimensional tolerances, as supplied to Pirelli General Cable Works Ltd. for use on C.E.G.B. contracts.

The three large 180 kV Porcelain bushings in the foreground are part of a consignment for the Canadian General Electric Co. Grinding and routine testing are the final stages before shipment to Toronto.

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Extra-high-voltage Power transformers

Three-phase ratings up to 600 MVA and 400 kV

Brown Boveri transformers are impulse tested, efficient, noteworthy for their compactness, and have a long-established reputation for reliability in service.

At present under construction :
two 400-MVA banks, 420 kV, for the Kraftwerke Hinterrhein A.-G., Thusis, Switzerland, and
one 420-MVA bank, 380 kV, for an installation in Finland

Single-phase transformer belonging to a 150-MVA bank for a Swedish 380-kV installation.

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Steam and gas-turbine power stations • Machinery and apparatus for nuclear power stations • Equipment for hydro-electric and diesel stations

Regulating and protective gear • Generators

Transformers, airblast circuit-breakers, instrument transformers for 400 kV

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BROWN, BOVERI & CO. LTD., Baden - Switzerland

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We are the largest manufacturers and suppliers of electrical insulating materials in the range we cover and the variety of our products

MICA ; block, splittings and fabricated parts.

MICANITE ; built-up mica insulation of every type in the form of sheets, tubes, cylinders, V-rings, covered bars, segment separators, fabricated parts, etc.

"SAMICA": mica paper insulation.

PAXOLIN ; synthetic resin bonded laminates having paper, fabric, glass, nylon, asbestos or other fillers are bonded with ethoxyline, melamine, phenolic, silicone or other resins to produce various grades for punching, moulding or machining.

SILICONE INSULATION ; a range of materials for Class H applications; silicone glass fabric, silicone bonded glass laminates, silicone bonded Micanite sheets, tubes, V-rings, etc., silicone glass/mica tapes; silicone combination insulation and silicone elastomer tapes.

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COPPER FACED PAXOLIN : HIGH VOLTAGE BUSHINGS & INSULATORS; for all voltage ratings and for indoor and outdoor equipment.

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PVC POLYTHENE & OTHER THERMOPLASTICS ; extrusions and injection mouldings of all types including PVC sleevings.

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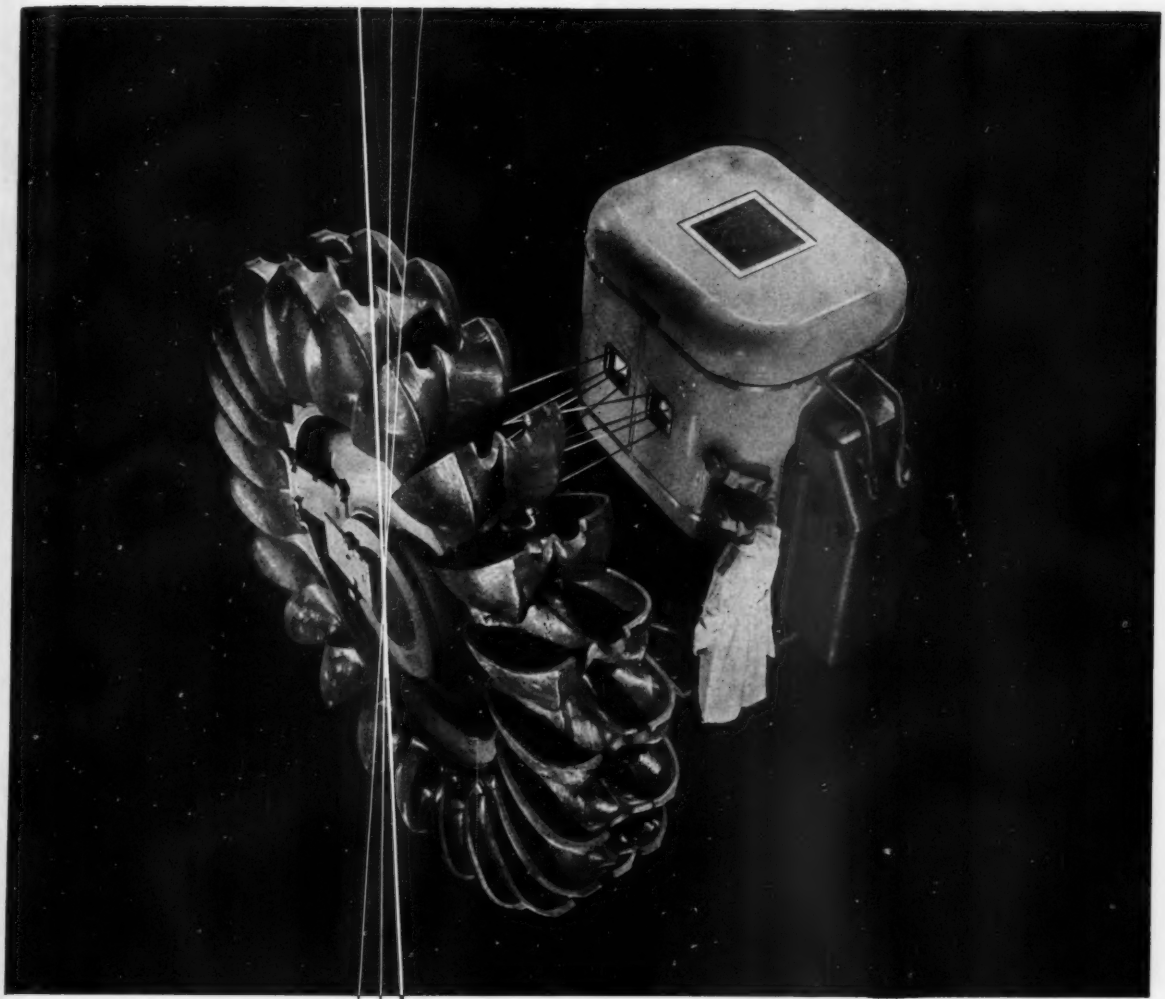

Radiographic Inspection of an Impulse Runner
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Diameter : 3.5 m (11' 6")
+GF+ steel grade : N4L 55 (2% Ni)
by means of our Brown Boveri – Broad Beam Stereo 31 MeV-Betatron

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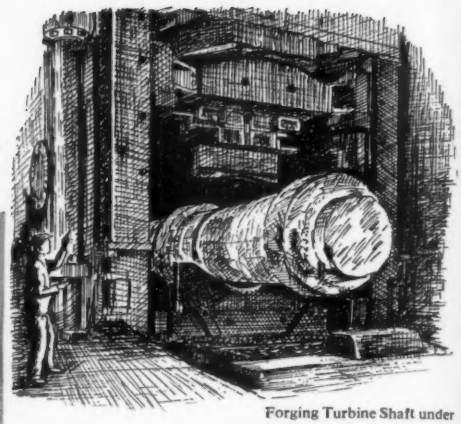
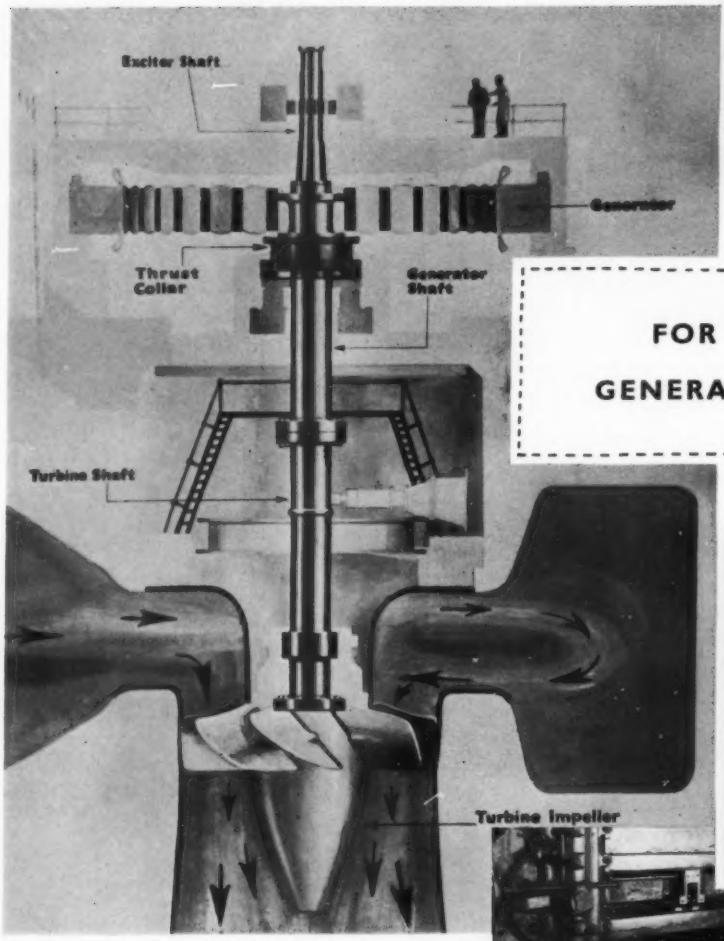
Steel Forgings...



Forging Turbine Shaft under 7,000 ton Electro-hydraulic press.



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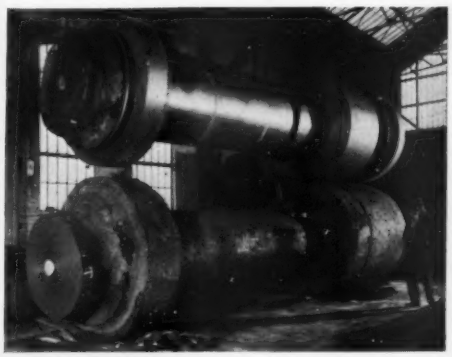
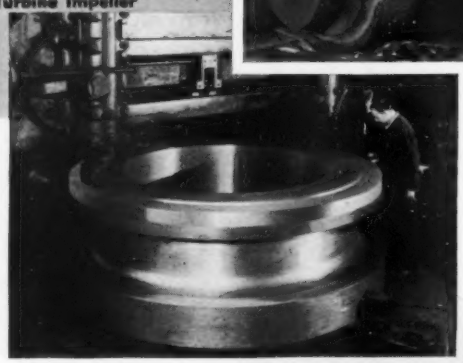
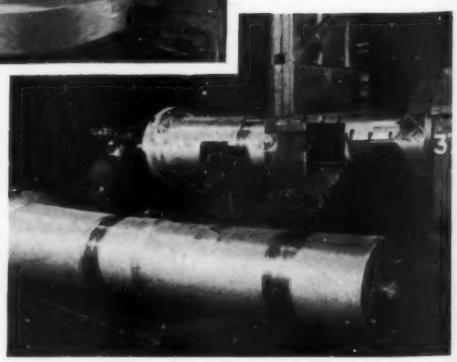




Rough machined and black forged steel Turbine Shafts, 22′ 11″ long.

Machining forged steel Thrust Collar, weight 18¼ tons.

Forged steel Exciter Shafts, each weighing 8¼ tons.



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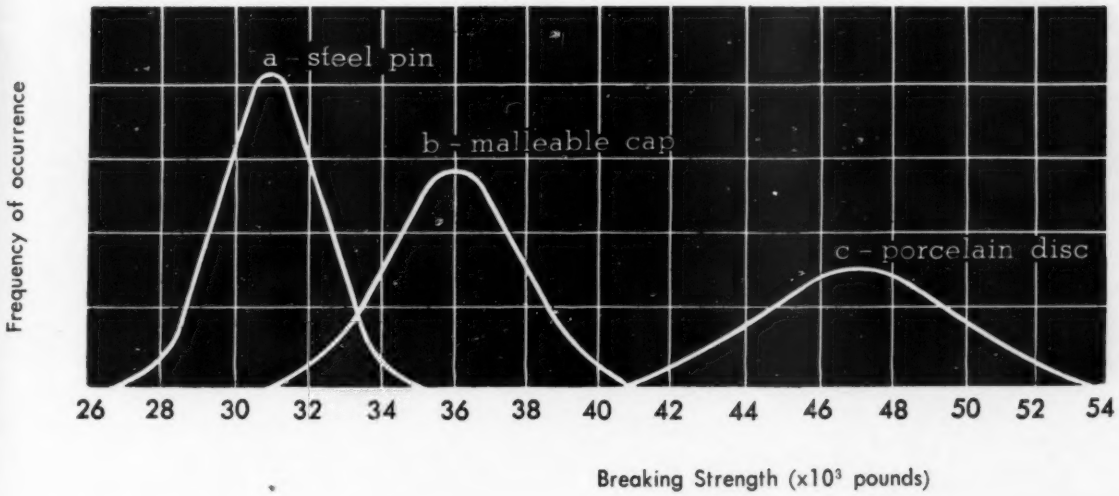
a - steel pin
b - malleable cap
c - porcelain disc
Frequency of occurrence
26 28 30 32 34 36 38 40 42 44 46 48 50 52 54
Breaking Strength (x10³ pounds)

UNIFORMITY
STRENGTH
DURABILITY

UNIFORMITY? . . . . . no matter how good an insulator you choose you can't expect maximum efficiency and service unless they're uniformly balanced in strength.

Take, as an example, the standard NGK 10″ ball and socket disc insulator (rated 25,000 lbs. E & M Strength) and review the mechanical strength of each component by the histogram above. Uniform mechanical breakdown strength, always occurring at the pin, of the NGK Insulator unit is shown by Curve a; that of the cap by Curve b when a special pin is used; that of the porcelain by Curve c when using a special high strength cap and pin.

Insulator uniformity at a high level is your prime assurance to safe operation and maintenance economy.

You get so much more out of **NGK** *Insulators*

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Cable: INSULATOR Nagoya. TELEX: NGK-NG9928
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Through a wide range of sizes and pressures, wood stave pipe is the economical choice of engineers for high-line conduits, penstocks and irrigation projects.

Our recent publication: *CONTINUOUS STAVE WOOD PIPE*, reveals details of history, uses, construction and maintenance, together with design data and flow tables. Write for your copy.

CANADIAN WOOD PIPE & TANKS LIMITED

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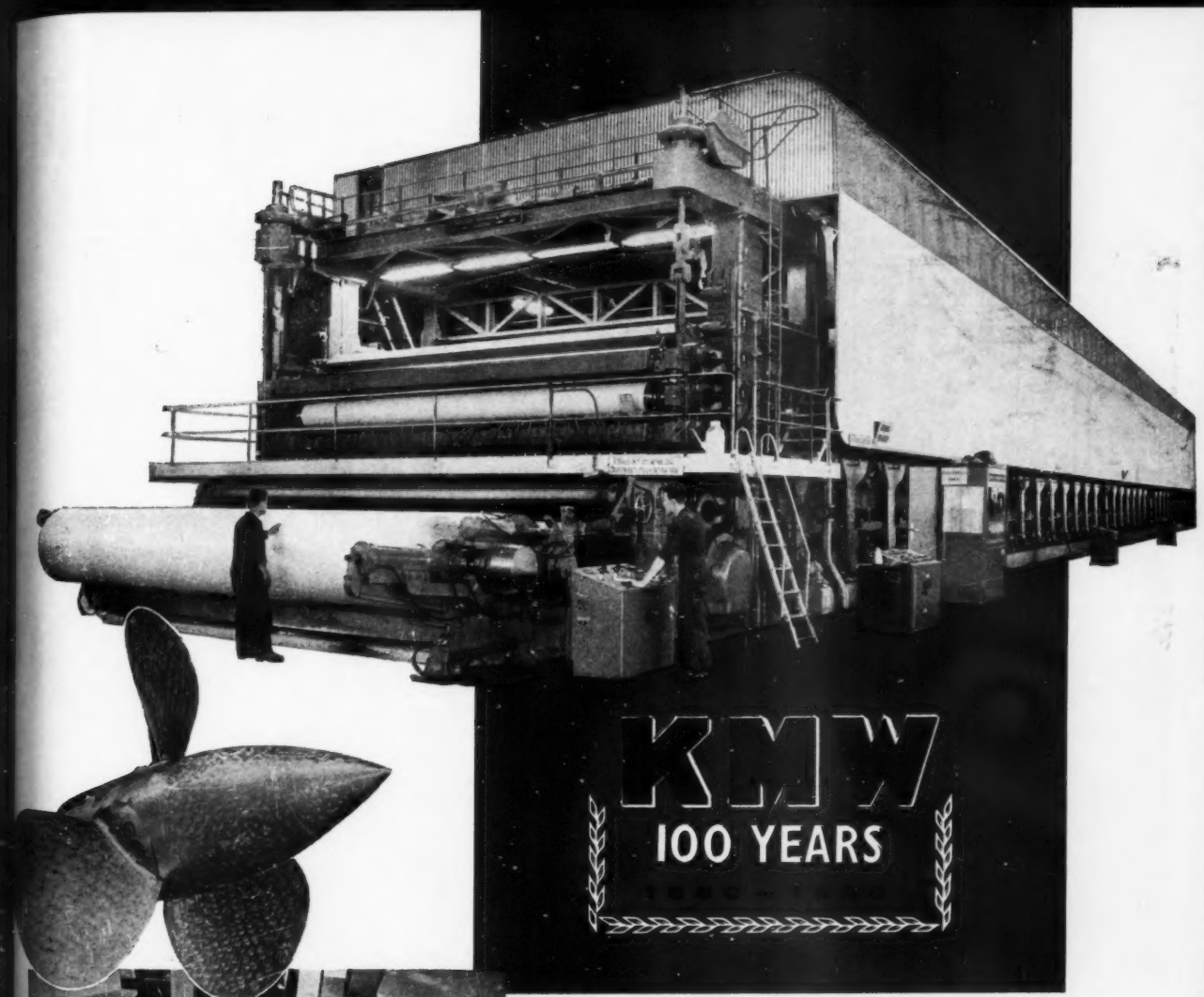
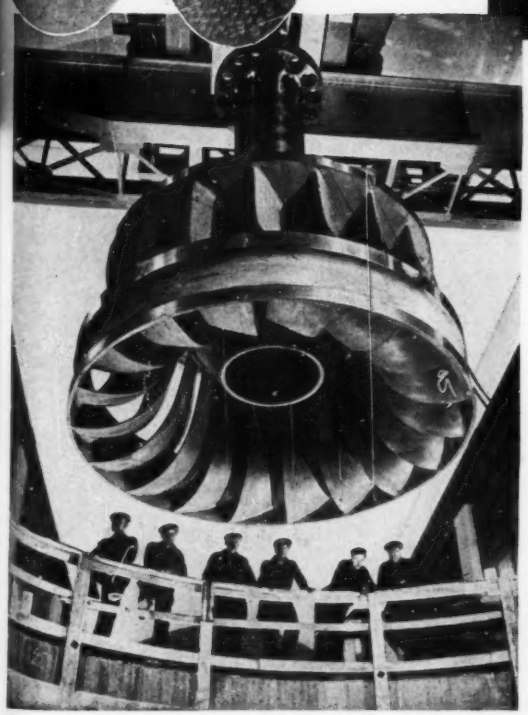
Canada





This year AB Karlstads Mekaniska Werkstad—a Swedish heavy industry with world-wide fame—enter into a new century of activity. In 1860 a small machine-shop and foundry were established on the site of the present works at Karlstad. The firm attained its present status in 1873, and in the late seventies KMW began to manufacture the products which later made the firm's name known the world over, i.e., machinery for the pulp and paper industries.

Development proceeded rapidly, and in 1897 Kristinehamns Mekaniska Werkstad was purchased by KMW. The manufacture of water turbines was subsequently concentrated at Kristinehamn, and these products also became well-known all over the world. The third main branch of manufacture was developed in 1936 when KMW started to make controllable-pitch KaMeWa propellers, now delivered to a wide variety of ships of many nations.

The 100th anniversary celebration will include the completion of a new plate shop and a large new research laboratory for further development of KMW paper machines. For their other main products, water turbines and propellers, KMW have modern laboratories which are among the best equipped in the world.

KMW is well equipped to meet a new century.

AB KARLSTADS MEKANISKA WERKSTAD

KARLSTAD · SWEDEN

ASEA Electro-hydrauli

Governors

are controlling today

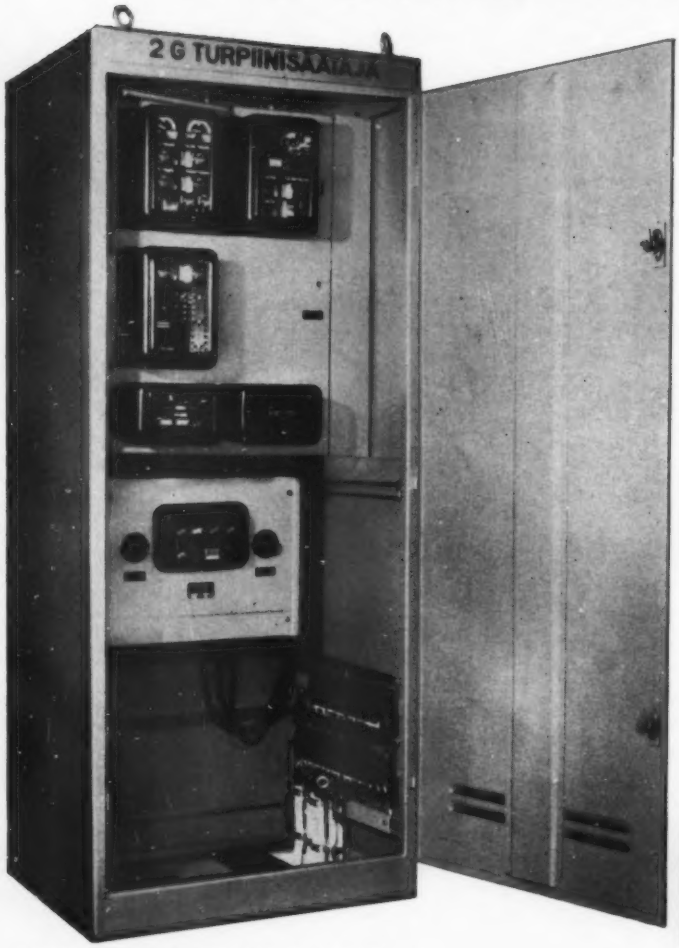
8,5 million horse powe

Since the first ASEA governor of commercial design went into operation in 1944, ASEA has delivered, or has now on order, governors for a total turbine output of more than

11,000,000

h. p.

Among these are also governors for steam and ga turbines.



Cubicle for an ASEA electro-hydraulic governor for a 200,000 h.p. Francis turbine.

Reference list

Country	Number of governors	Turbine output h.p.
Australia	6	385,000
Austria	6	263,000
Brazil	4	800,000
Canada	9	380,000
China	1	11,000
Finland	15	660,000
France	4	240,000
India	1	57,000
Japan	17	1,230,000
Norway	9	560,000
Sovjet Union	5	96,000
Spain	2	37,000
Sweden	100	6,320,000
Venezuela	2	27,000
Yugoslavia	2	72,000
Total in April 1960	183	11,138,000

To the right

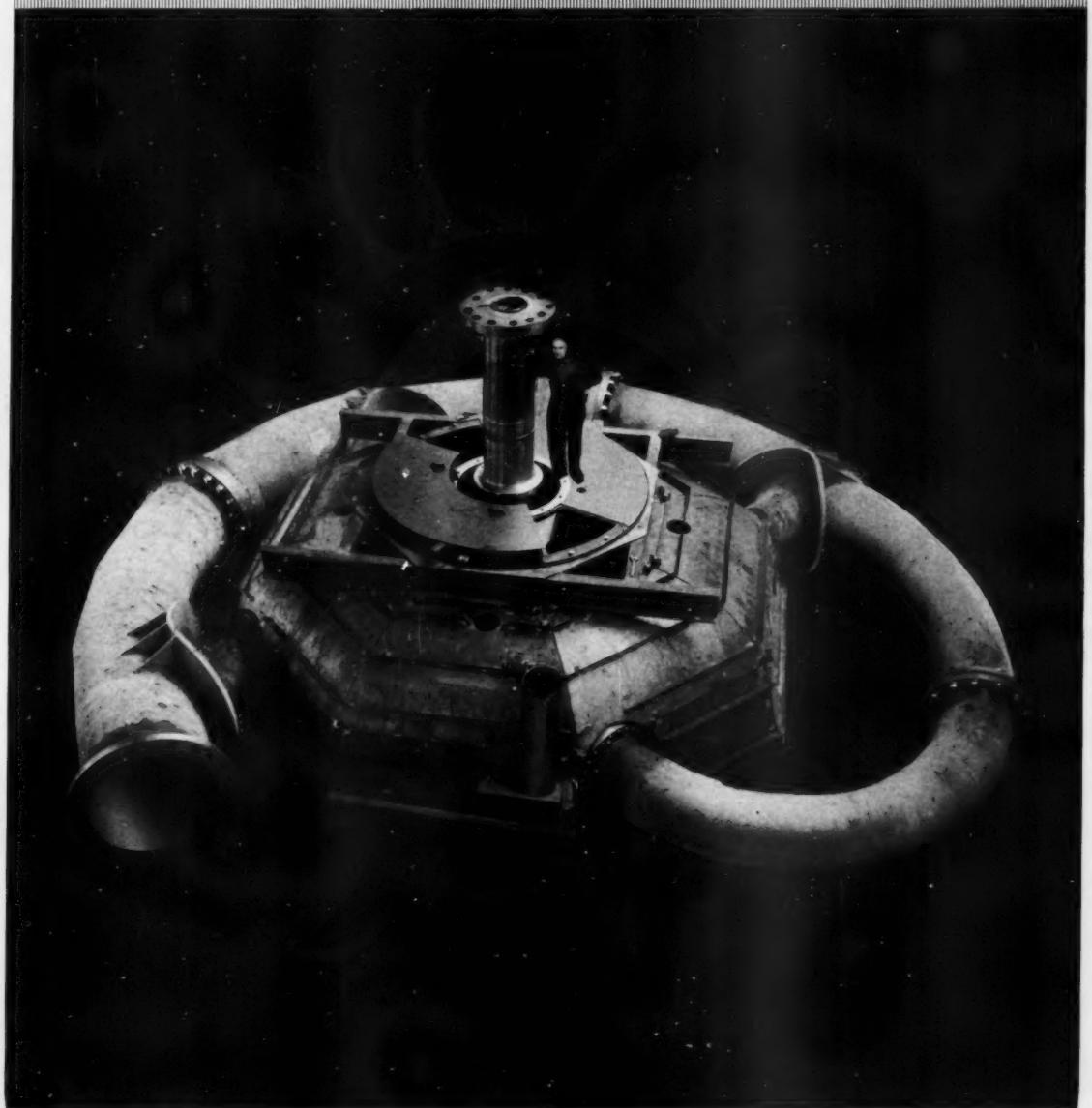
Interior view of the Swedish power-station Stornorrfors with three 150,000 kVA ASEA generators. The turbines are equipped with ASEA electro-hydraulic governors.

To the left

Complete electro-hydraulic governor delivered by ASEA in 1948.

WAT

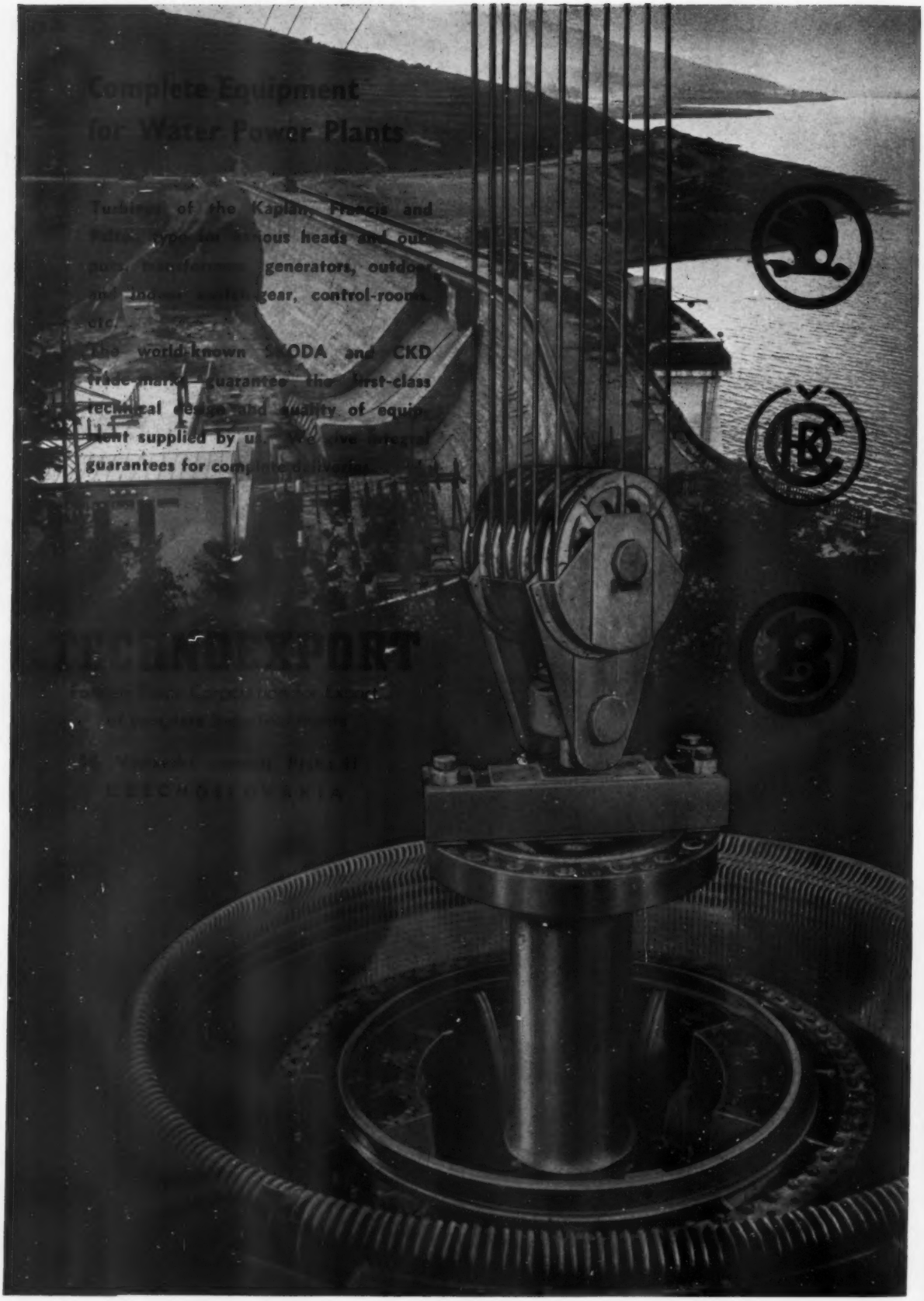
CHARMILLES



HYDRAULIC TURBINES

—CHARMILLES ENGINEERING WORKS LTD., GENEVA—

TWO 88,000 HP VERTICAL SHAFT, FOUR-JET IMPULSE TURBINES FOR BRAZIL


Complete Equipment
for Water Power Plants
Turbines of the Kaplan, Francis and
ious heads and out
generators, outdoor
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etc.
The world-known ŠKODA and CKD
trade-marks guarantee the first-class
technical design and quality of equip-
ment supplied by us. We give integral
guarantees for comp

133,000 kVA water wheel generator for Okutadami Power Station

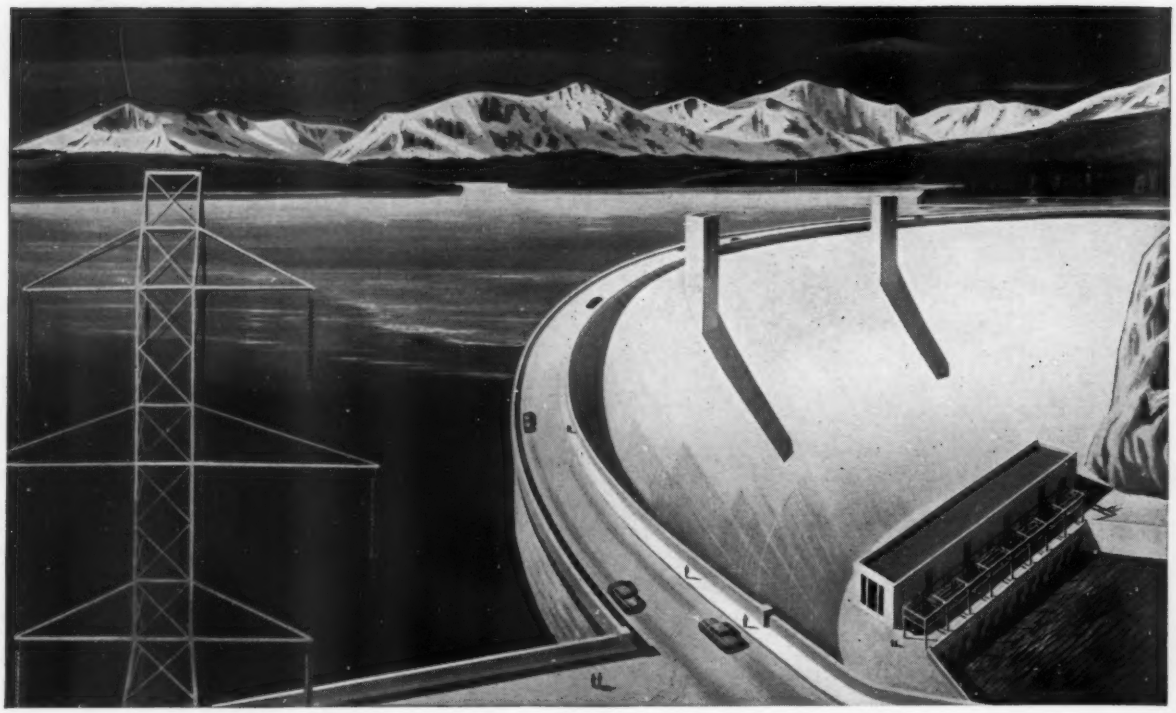
Toshiba

Contributing to Your Better Living !

Heavy electric equipment for domestic and overseas use is being sent out one after another from Toshiba's Tsurumi Works.
Shown here (right) is one of the 3 scheduled 133,000 kVA generators—the second largest in the world—to be installed at Okutadami Power Station in central Japan.
You can also see part of the 58,000kVA generator at the corner of the picture, which is now in operation at Mazatepec Power Station in Mexico.
And. . . Toshiba is working on the next one.

TOKYO SHIBAURA ELECTRIC CO., LTD.

2, Ginza Nishi 5-chome, Chuo-ku, Tokyo, Japan. Cable: TOSHIBA TOKYO



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- **Pumping and Filtration Plants**
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HYDROELECTRIC DIVISION

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One of three 96-inch **Howell-Bunger** valves in operation at the U. S. Engineers Mud Mountain Dam, White River, Wash.

2 ways to air-cushion a big splash

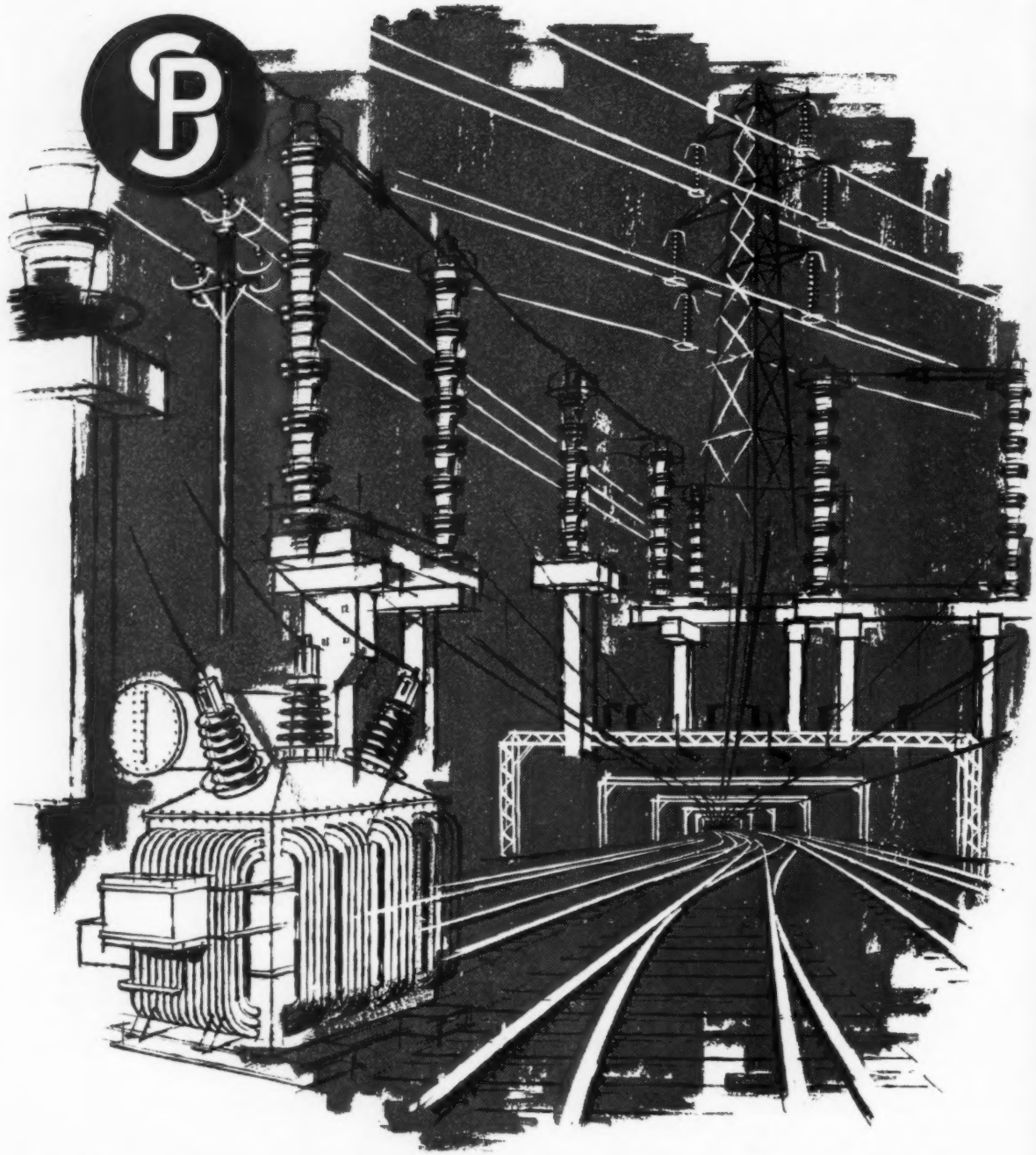
...and provide easy regulation of free discharge

***Howell-Bunger* valves** produce an expanding, aerated water jet that dissipates tremendous energy with minimum erosion and cavitation — and virtually no vibration. They're ideal for free discharge with high to low heads, into atmosphere or water. Lowest in initial cost... economical to install (need pipe line or conduit of *minimum* size). Only one moving part in contact with flow.

***Ring-Jet* valves** yield a concentrated, aerated jet, perfect for locations requiring reduced spray. A logical development from the *Howell-Bunger* valve, they offer many parallel advantages ... are equally suited to high and low heads.

Only Allis-Chalmers is geared to equip complete hydro installations — turbines, generators and auxiliaries. Contact our office in your area for information. Or write **Allis-Chalmers,** *Hydraulic Division, York, Pennsylvania.* A-1256

One of two RING JET valves used for irrigation bypass from Tulloch Dam, California.



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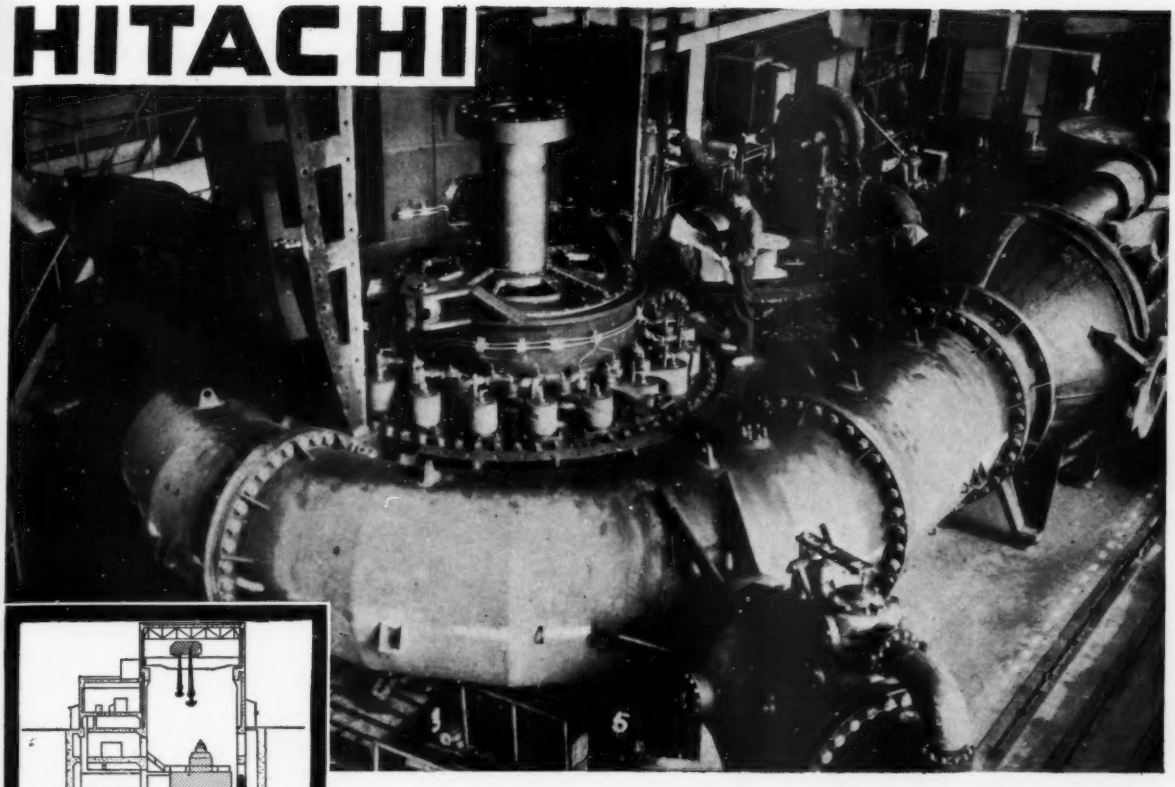
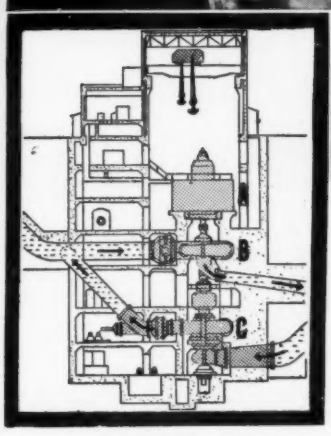
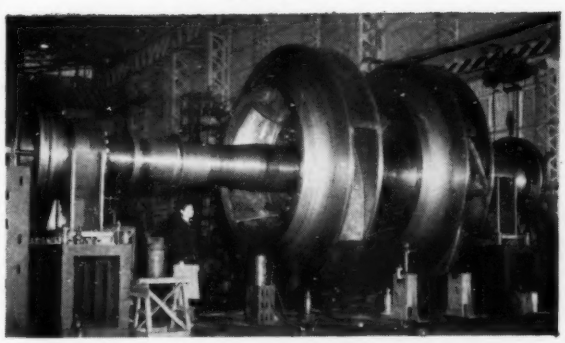




A Generator-Motor
B Turbine
C Pump

▼ Pump Impeller



Pump and Turbine Completed for the Huge Pumped Storage Power Station

Hitachi, Ltd. has recently completed a mammoth vertical shaft 56,500 kW turbine pump for delivery to the Morozuka Pumped Storage Power Station in Japan to surpass world level in this field. This turbine pump is scheduled to be installed with a 58,000 kVA/56,500 kW generator-motor and a 53,000 kW turbine, also of the Hitachi make.

This pump is to be operated on surplus power when it becomes available on such occasions as rainy seasons or midnight operations for pumping up water to the reservoir. The water stored this way is used to increase power output of the station in the peak-load period.

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO

The Specifications of the various parts are as follows:

Pump	Quantity	18.6 m^3/s
	Total Head	241.4 m
	Speed	300 rpm
Turbine	Effective Head	222 m
	Output	53,000 kW
	Speed	300 rpm

Generator-Motor	Output	58,000 kVA (Generator)
		56,500 kW (Motor)
	Voltage	11,000 V
	Current	3,045 A
	Frequency	60 cycles
	Speed	300 rpm

Beside the above, Hitachi, Ltd. also made and delivered automatic operational control equipment, transformers, switchboards, A.C. circuit breakers, overhead travelling cranes and other equipment for the Morozuka Power Station.

Where DEEP DIGGING and LONG REACH are required to remove HUGE QUANTITIES of materials at LOWEST COST...

BUCYRUS-ERIE WALKING DRAGLINES

are first choice

The walking dragline operates on a 'tub' that gives it great floatation. Its walking system is simple and its greatly increased stability over normal excavators allows the operator to use longer booms and to reach a greater working area from each set position, thus reducing the number of moves. Maintenance is low compared to any other type of excavator and for certain types of work its capacity is bigger and its dirt-per-hour cost is lower. Although the traction of the walking dragline may be of lower speed in comparison with the crawler type its unique manœuvrability more than makes up for the slightly lower move-up speed.

The Bucyrus-Erie 770-B Ward-Leonard electric walking dragline in the illustration weighs approximately 850 tons and the boom can be either 190′ or 225′ in length, carrying a bucket of from 14 to 20 cubic yards capacity. A similar machine to this will shortly be installed in Australia to fulfil an order placed by Electricity Trust of South Australia and it will be the largest dragline excavator ever imported into that Continent. The machine, when installed, will be employed stripping over-burden at an estimated rate of 800 tons per hour, excavating 24 tons in each working cycle of operation from a depth of 140′ and depositing the material to a dump 100′ high by means of its 240′ boom. The electric motors used for its operation will aggregate 1500 h.p.

BUCYRUS-ERIE COMPANY
South Milwaukee, Wisconsin, U.S.A.
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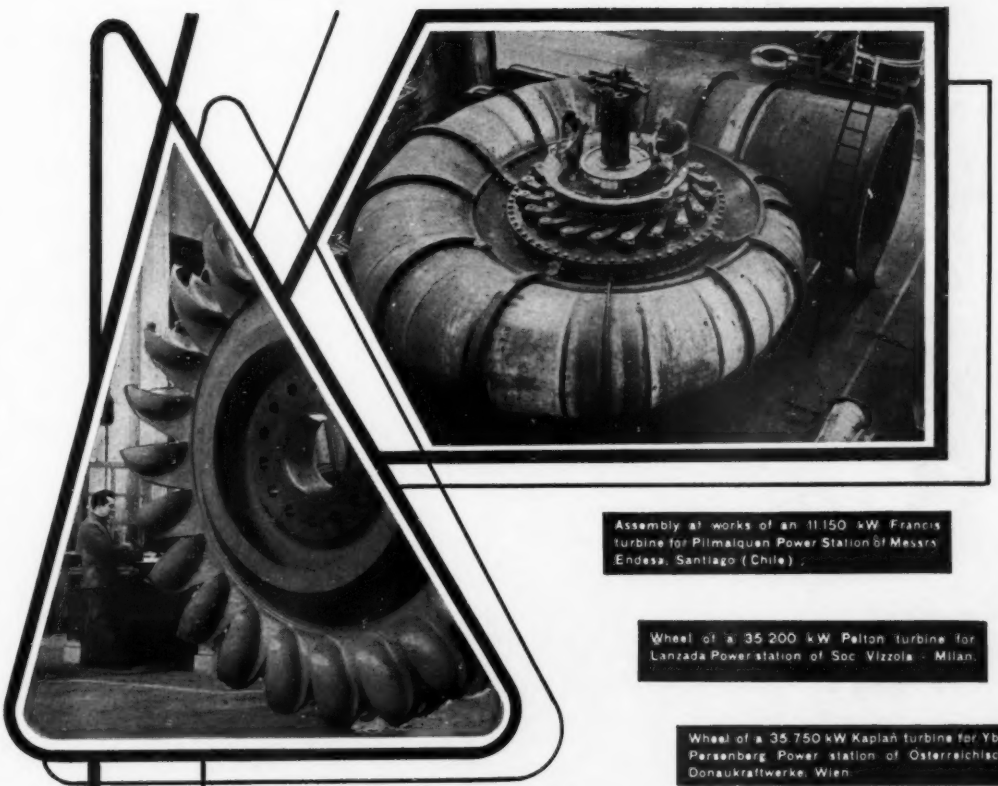
BUCYRUS ERIE

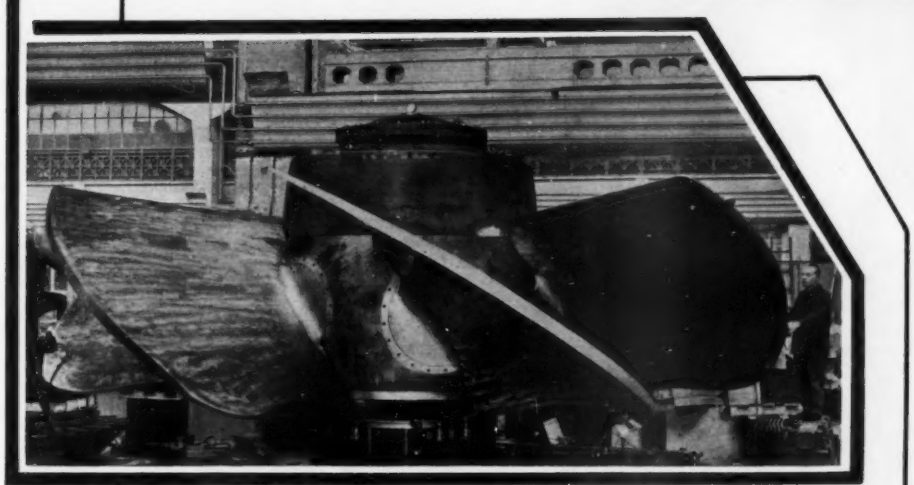
Complete hydro-electric plants



Assembly at works of an 11.150 kW Francis turbine for Pilmaiquen Power Station of Messrs Endesa, Santiago (Chile).

Wheel of a 35.200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan.

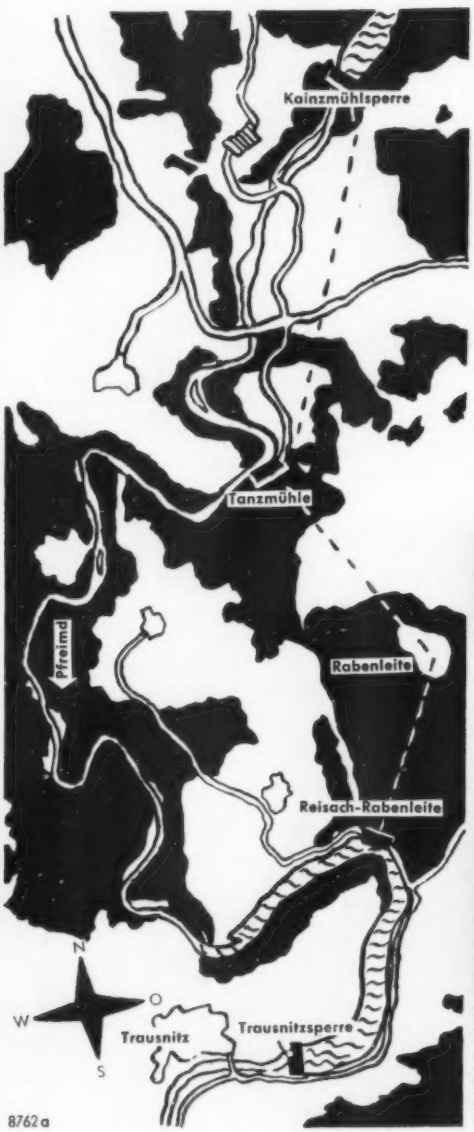
Wheel of a 35.750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.



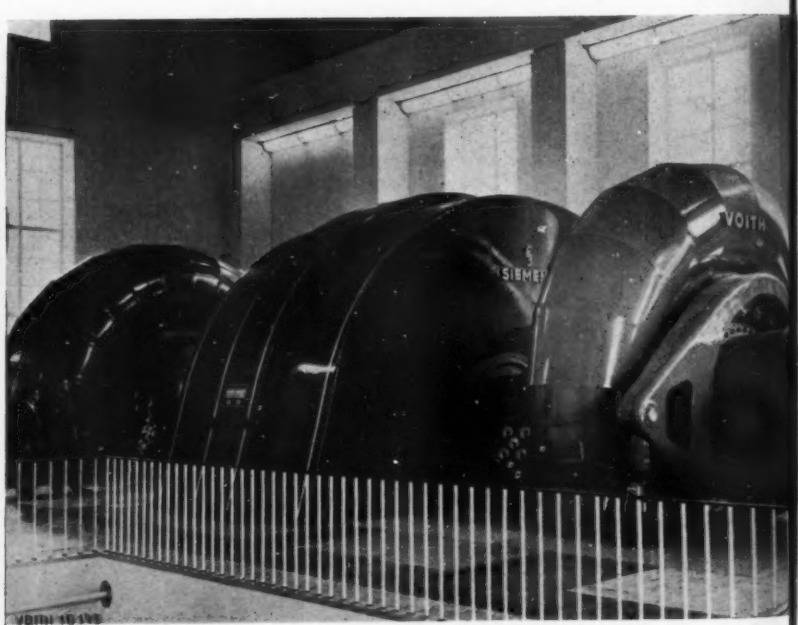
ANSALDO-SAN GIORGIO
GENOVA

The TANZMÜHLE Hydro-Electric Power Station—

the last member in the 'Jansen' Chain



This power station is equipped with
a 38,000 hp Francis spiral turbine operating under 426 ft (130 m) head, water discharge 862 cusecs (24,4 m^3/s), speed of machine set 375 rpm;
a 31,300 hp single-stage double-suction storage pump delivering 572 cusecs (16,2 m^3/s) against 416 ft (127 m) head;
a spherical valve for the turbine, a needle valve, a sliding gear coupling for the storage pump, and an automatic governor.



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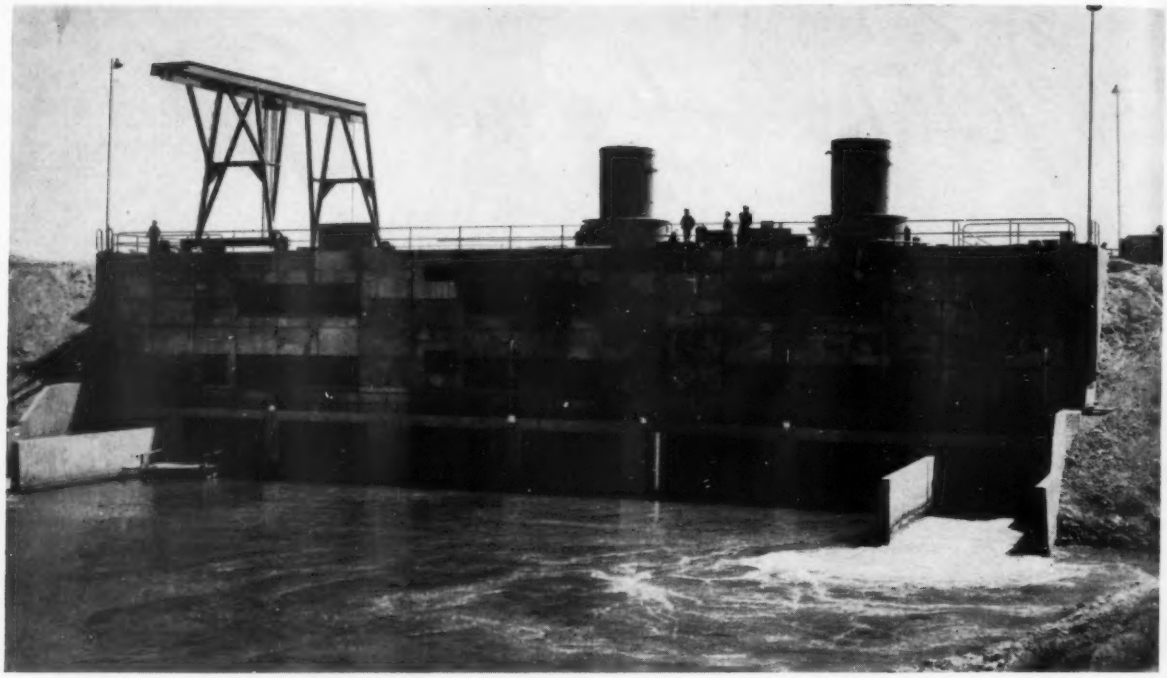

2 Leffel Turbines Help Provide Power for Peace at the Girishk Power Development in Afghanistan

Close up of Generator Unit #2 at Girishk, showing two Afghan employees of Morrison-Knudsen Afghanistan, Inc. in native dress. Photo at top of page shows downstream side of Girishk Power Plant. Mechanical gallery is on lower deck, electrical gallery on upper deck.

Typical of the job being done by Leffel turbines in all parts of the world — wherever efficient development of water power resources can contribute to peace and prosperity — is the Girishk Power Plant in southwestern Afghanistan.

This plant was designed by International Engineering Company, Inc., and built by Morrison-Knudsen Afghanistan, Inc. for the Helmand Valley Authority, an agency of the Royal Government of Afghanistan. Designed for three 1500 KW generators, the plant was completed in June, 1958 with two generators installed, each driven by a Leffel vertical shaft turbine developing 2200 H.P. at 187.5 R.P.M. with a net head of 25 feet.

Thousands of installations such as this one have helped build Leffel's reputation for high efficiency, long life and reliable service. And every Leffel turbine is backed by more than nearly a century of experience. That experience is available to you, without obligation, whether your project is a new installation or the expansion or rehabilitation of existing facilities. Just write, outlining your requirements.

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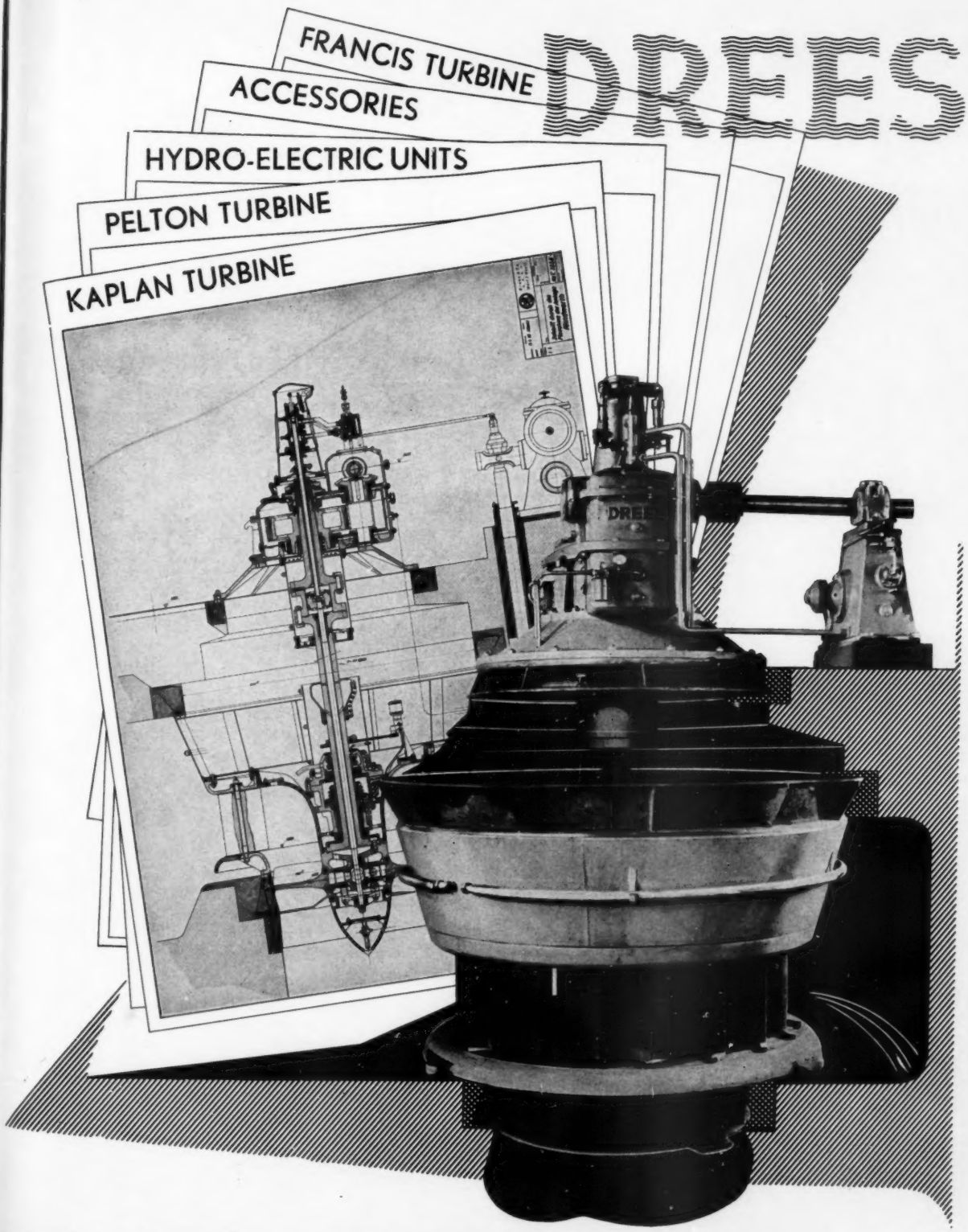

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VÖEST

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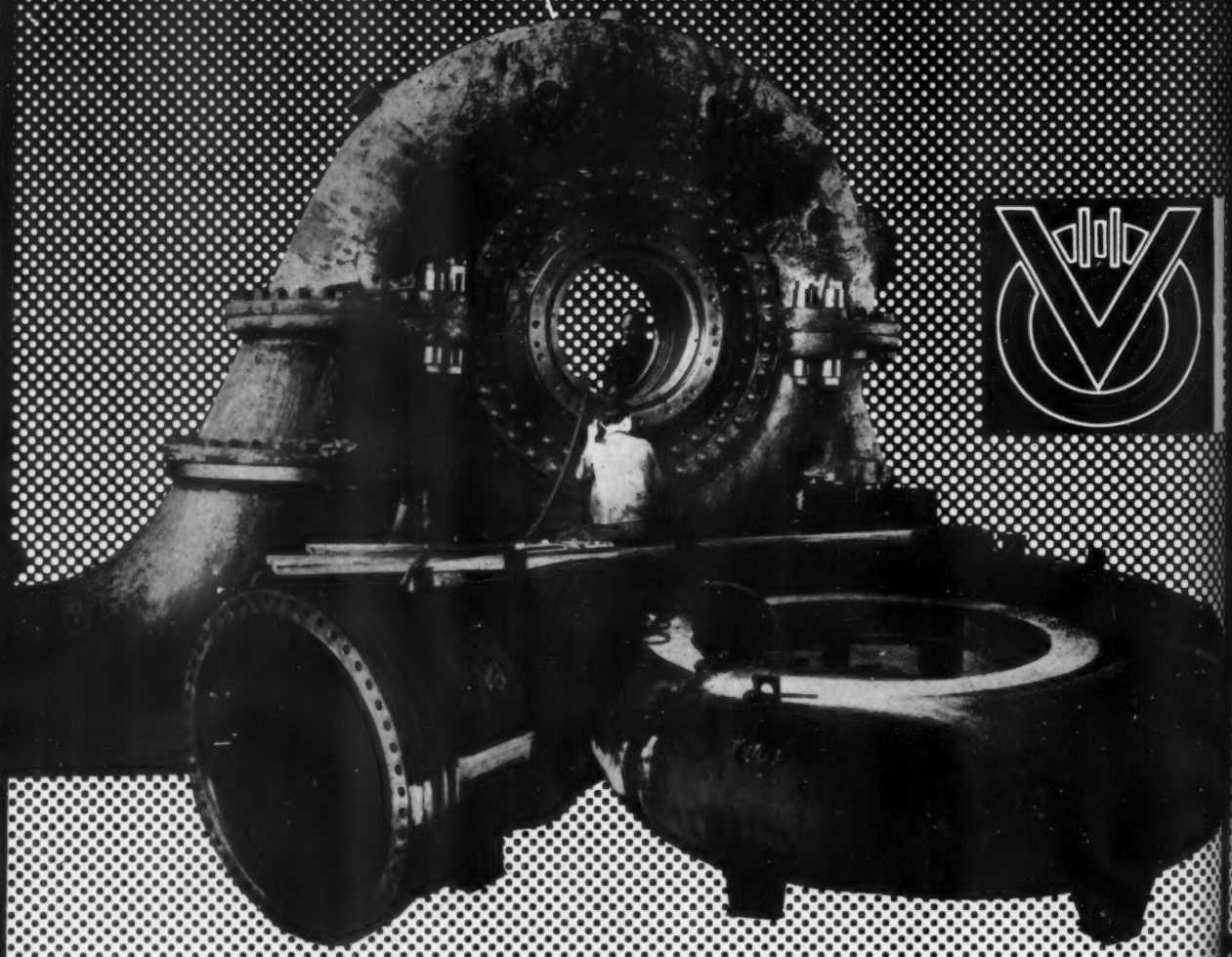

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Steel structures for weirs and loch gates of every type, including the required auxiliary equipment; mechanical and hydraulic drives hereto sprocket chains; trash rake cleaning machines; weir cranes.

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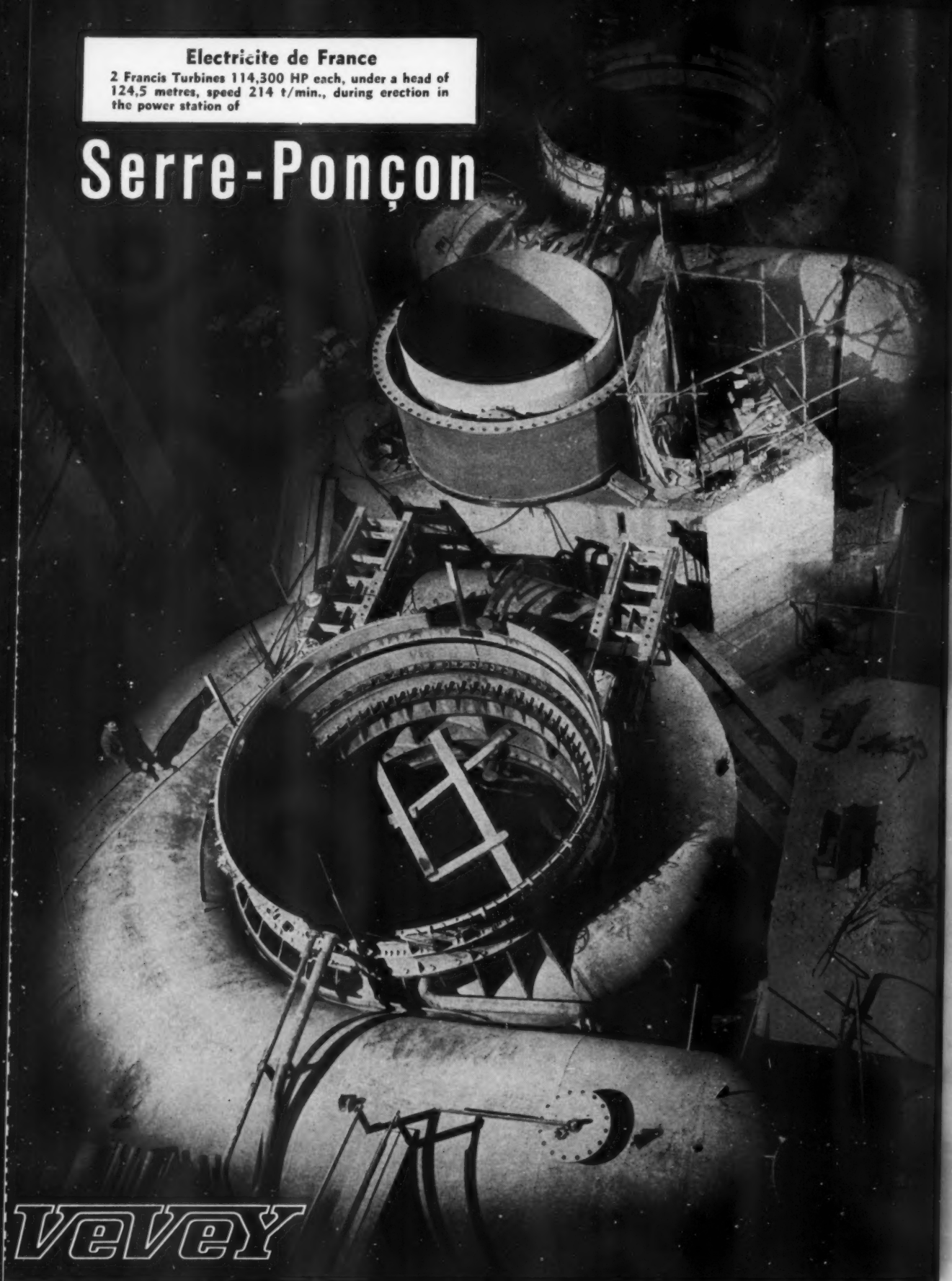
Electricite de France

2 Francis Turbines 114,300 HP each, under a head of 124,5 metres, speed 214 t/min., during erection in the power station of

Serre-Ponçon



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Once again Mitchell Construction are driving hard rock tunnels in the Scottish Highlands at the rate of over a mile a month.

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This is what is happening at Strathfarrar, Inverness-shire, where, in addition to 15 miles of tunnel, the Company are constructing two dams and two underground Power Stations for the North of Scotland Hydro-Electric Board.

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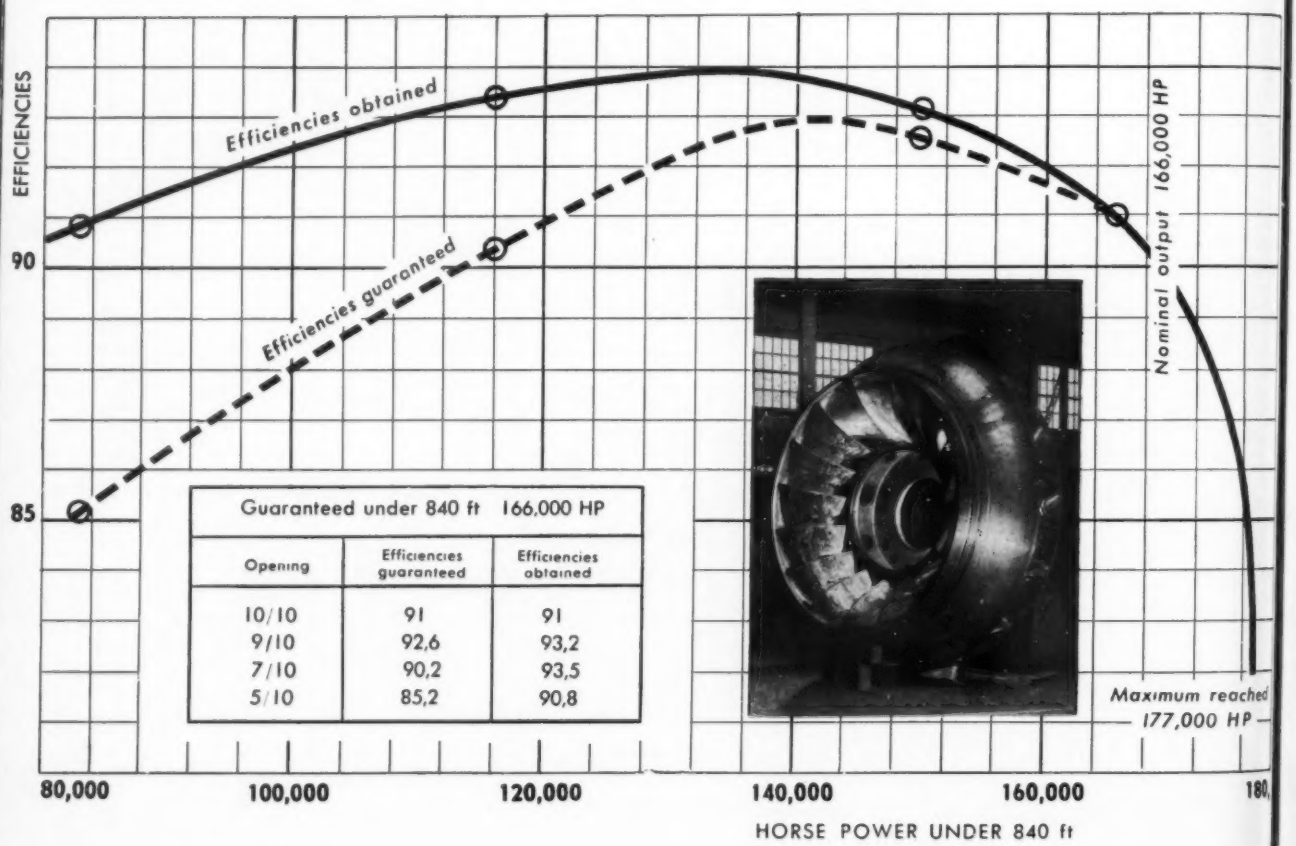

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Opening	Efficiencies guaranteed	Efficiencies obtained
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9/10	92,6	93,2
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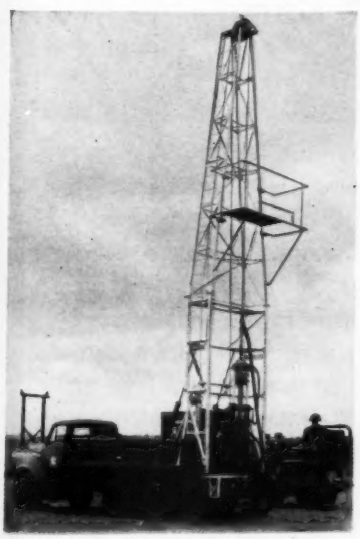

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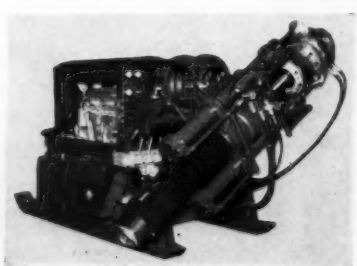

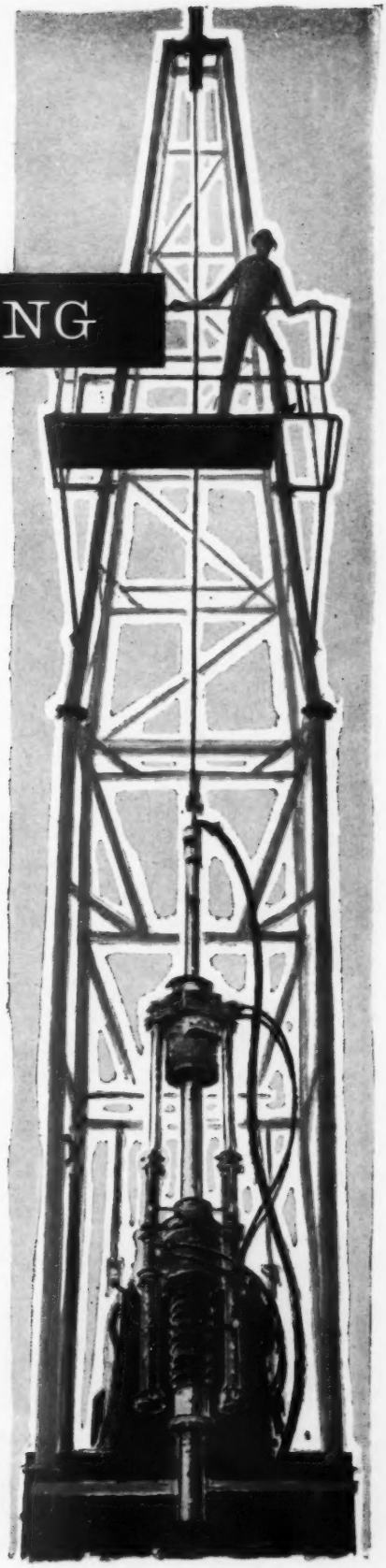

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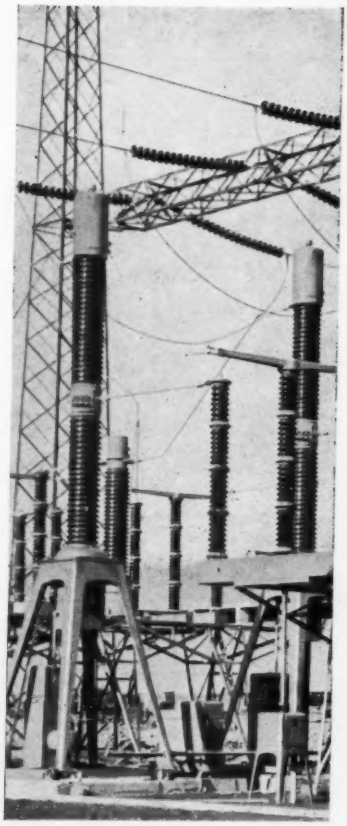
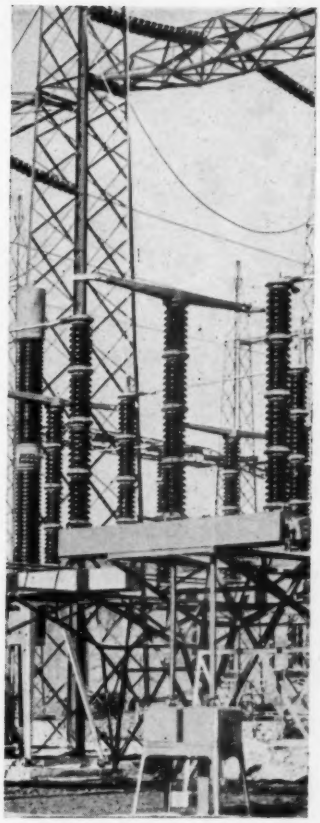
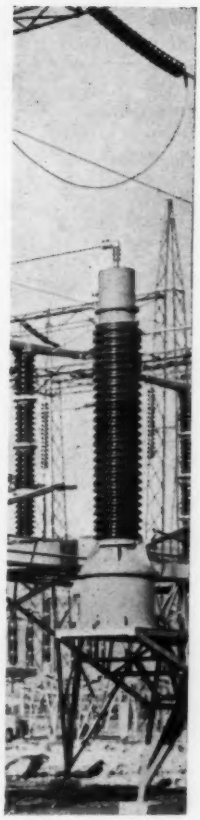




MILANO VIA LARGA 26 (ITALY)



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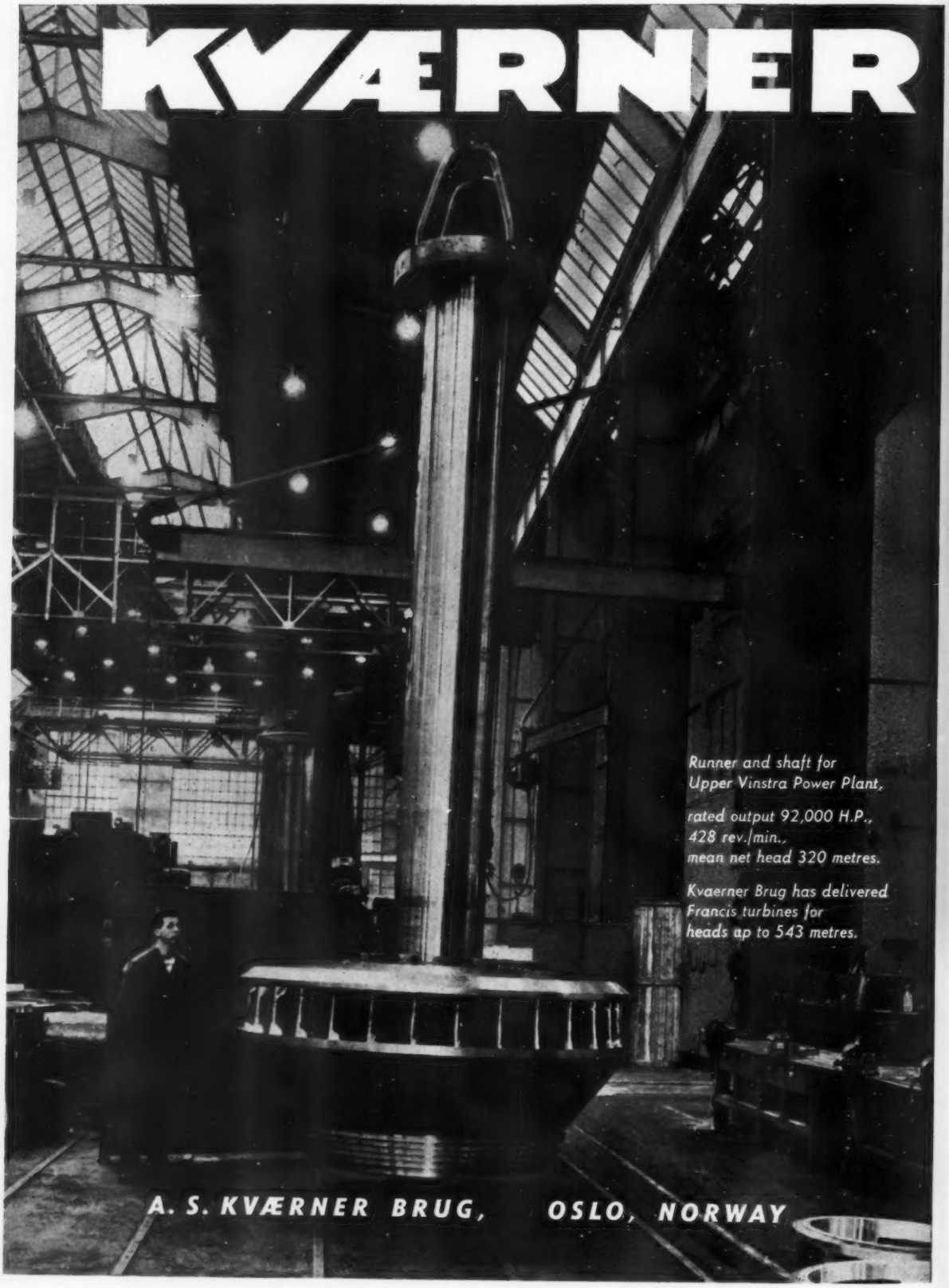
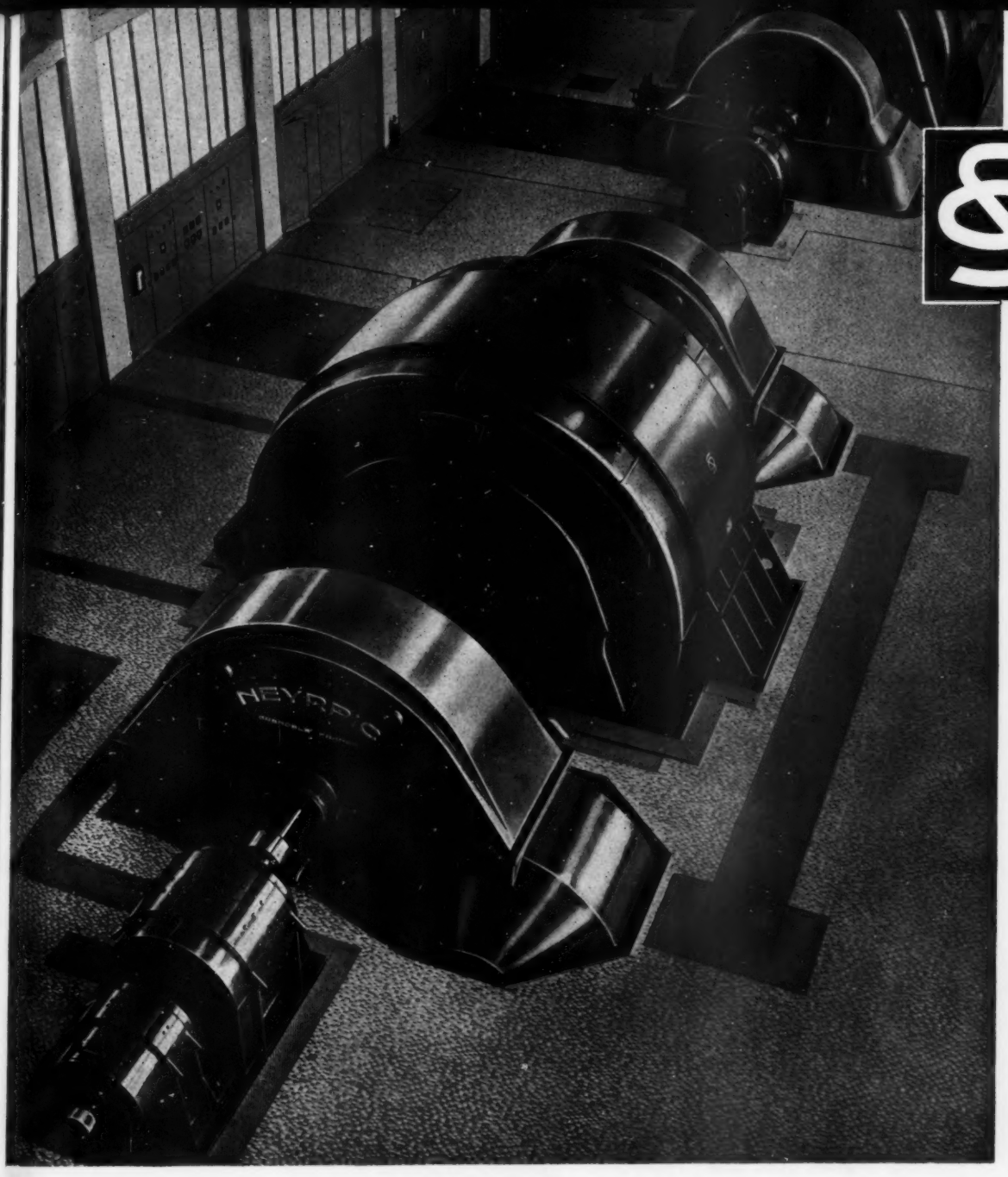
BUSHING INSULATORS
SWITCHBOARDS
METAL-CLAD SWITCHGEAR

FOR MEDIUM, HIGH
AND ULTRA-HIGH VOLTAGES


KVÆRNER
Runner and shaft for
Upper Vinstra Power Plant,
rated output 92,000 H.P.,
428 rev./min.,
mean net head 320 metres.
Kvaerner Brug has delivered
Francis turbines for
heads up to 543 metres.
A. S. KVÆRNER BRUG, OSLO, NORWAY



One 75 MVA three-phase synchronous generator, horizontal shaft, 428 r.p.m., 11,000 V ± 5%, 50 c.p.s. ± 5% coupled to two Pelton turbines of the overhanging type. This generator has been supplied to C.E.B. (Consorzio Elettrico del Buthier), Turin, Italy, for their Valpelline power station. This machine is the largest generator in the largest power station in the Aosta Valley.

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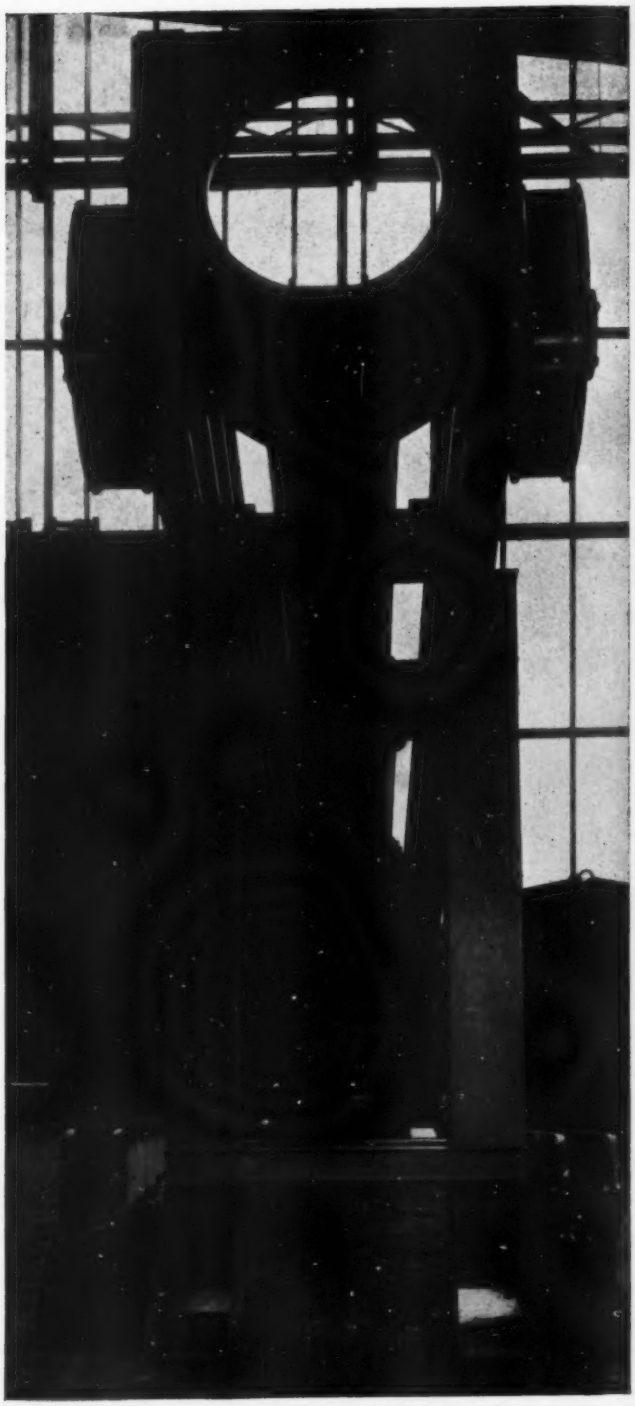
VIENNA **GRAZ**



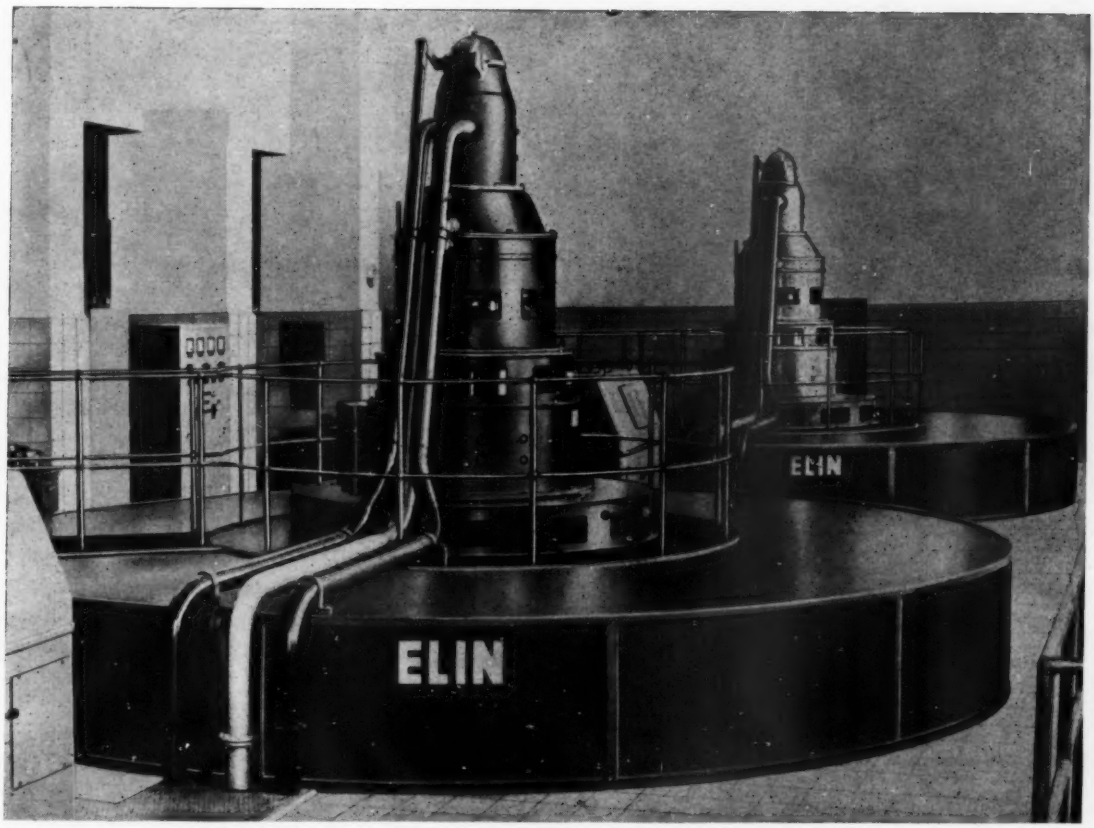
Oil hydraulic hoist
for operation of
turbine intake gates
11 x 12 m.

Lifting capacity
165 tons

3 hoists of this type have been delivered by us for the Bjurfors Power Station, Sweden

Head Office: VIENNA V., MARGARETENSTRASSE 70, AUSTRIA

VERTICAL SHAFT GENERATORS

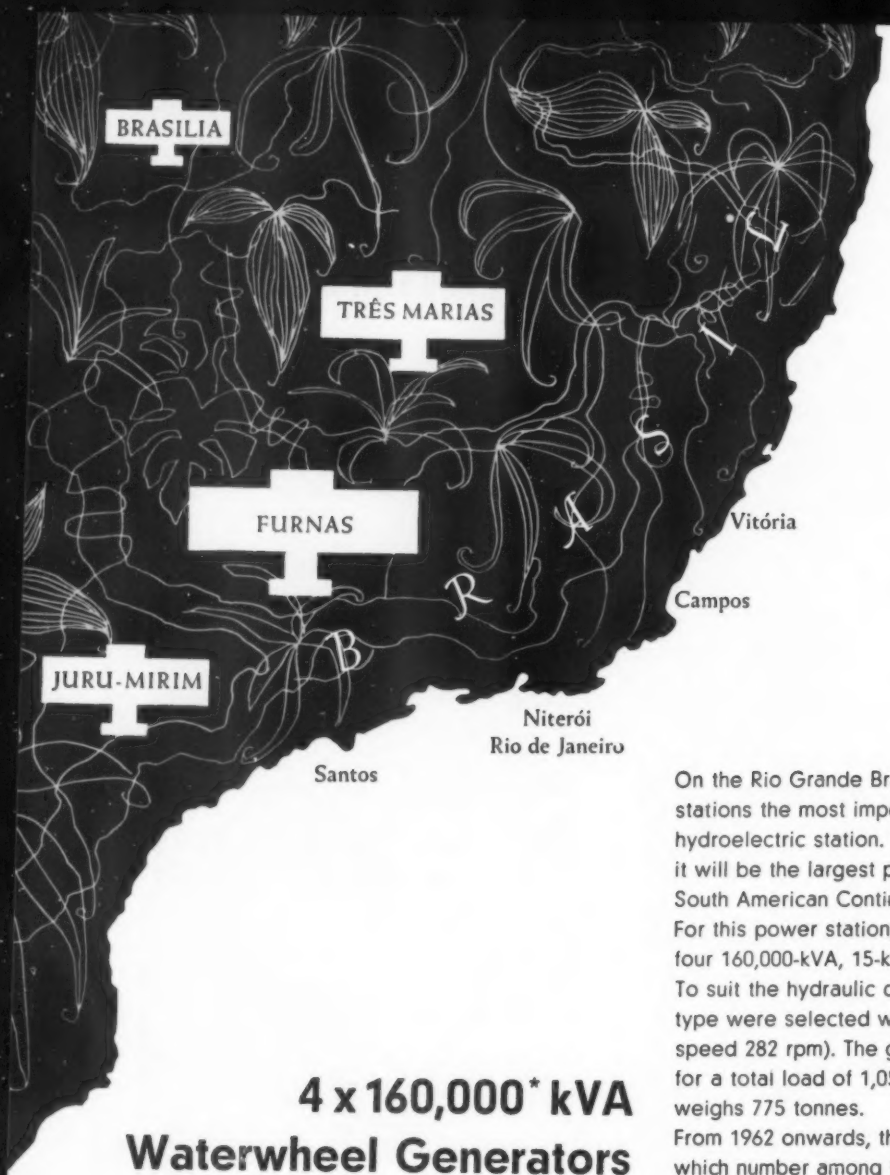


Two three-phase vertical synchronous generators, each 12,000 kVA (suitable for 15% over-load continuously), 6.9 kV,60 cps, 300 r.p.m., supplied for Hydro-Power Station El Oviachic, Mexico. A third generator of the same design has been installed at Hydro-Power Station, Mocuzari, Mexico.

ELIN-UNION

Aktiengesellschaft für elektrische Industrie

Vienna—Austria



SIEMENS

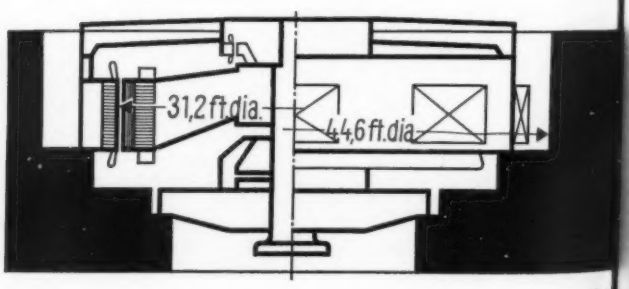
4 x 160,000* kVA Waterwheel Generators for Furnas

On the Rio Grande Brazil is erecting a new chain of power stations the most important link of which is the Furnas hydroelectric station. With an ultimate output of 1,280 MVA it will be the largest power station on the whole South American Continent.

For this power station, Siemens-Schuckertwerke are supplying four 160,000-kVA, 15-kV generators with a power factor of 0.95. To suit the hydraulic conditions, generators of the umbrella type were selected with a rated speed of 150 rpm (runaway speed 282 rpm). The generator thrust bearing is designed for a total load of 1,050 tonnes; the complete generator weighs 775 tonnes.

From 1962 onwards, these four Siemens generators, which number among the largest in the world, will feed 640,000 kVA into the Brazilian power system. Together with seven other generators intended for the hydroelectric power stations at TRES MARIAS, JURU-MIRIM and BRASILIA, Siemens generators will raise the capacity of the Brazilian power system by almost 1,000,000 kVA.

* corresponding to VDE rating of 4 x 175,000 kVA



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BERLIN · ERLANGEN

WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

Annually 40 shillings by post. Single Copies 2s. 6d.

Volume 12 Number 8

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SULZER

Penstocks Storage Pumps

for hydro-electric power stations

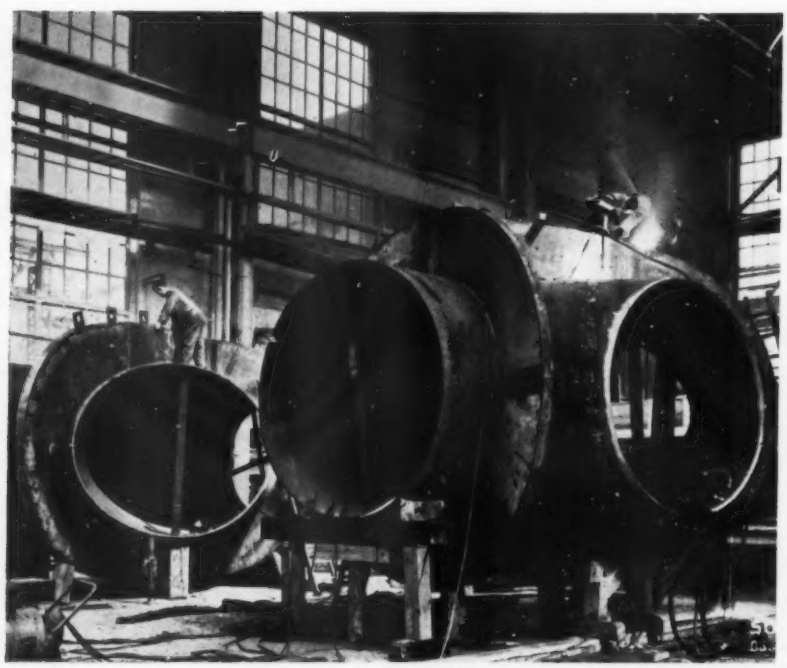
Sulzer Brothers are supplying the following equipment for the C. E. G. B. power station at Ffestiniog, North Wales:

in collaboration with Messrs. Marshall & Anderson Ltd., Motherwell

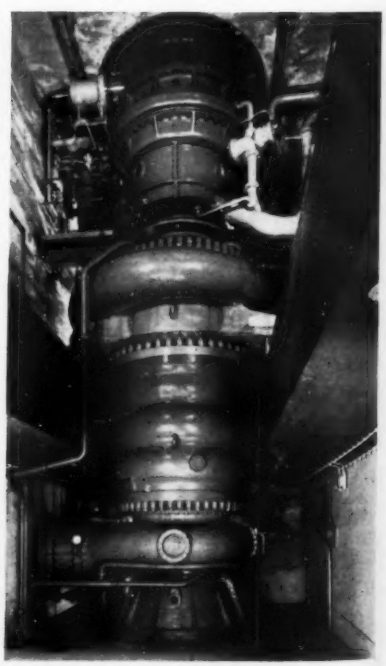
2 steel tunnel linings
4 penstocks
4 sets of branch and interconnecting pipes

in collaboration with The English Electric Co. Ltd.

4 high-lift storage pumps for the following working data:
Discharge 745 cu. ft. per sec.
Head 1,000 ft.
Max. input up to 110,000 H. P.



Fabrication of two branch pipes for Ffestiniog in the Sulzer shops at Winterthur. Inside diameter 7 ft. 6 in., service pressure 590 lb. per sq. in.



Sulzer five-stage high-lift pump in an Austrian power storage station. Discharge 49,250 g. p. m., head 3,186 ft., input 55,500 H. P.

SULZER

WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

Integration

"OCCASIONALLY, a water-resource project may feasibly serve the single purpose of hydro-electric power generation. This will normally occur only in remote areas where water supplies may be large and demands for other uses may be negligible." These words are taken from a paper presented to the recent World Power Conference by Mr. Floyd E. Dominy, the Commissioner of the Bureau of Reclamation of the United States Department of the Interior. They show, in a single sentence, the trend which is now spreading throughout the world, for a broader look at natural resources of all kinds. The integration of water power into the national energy economy is taking place much more rapidly than ever before. It is becoming difficult to consider any source of energy in isolation.

In all these broad evaluations of national energy resources, it is becoming clear that hydro power has an increasing value as the years go by. Coal resources do not change their value, because the method of utilising them for power generation is inflexible. The only change in that field may be a revision of viewpoints on the question of generating power near to the coalfield and transmitting it electrically, or carrying coal by some form of transportation to power stations near the load. But the thermal station, although its efficiency in utilising the energy in the coal creeps slowly upwards, cannot provide any element of storage; as systems grow larger there are the added complications of providing special types of plant (perhaps gas turbines in addition to steam plants) for dealing with peak load. Nuclear energy, as mentioned before in these columns, is greedy of load factor, and must be fed with the best of the load to make it economically worthwhile to employ plant costing perhaps three times as much per installed kilowatt as conventional thermal stations, although this ratio is decreasing. The thermal stations will therefore suffer inefficiency as the nuclear plants begin to take the best of the load.

Thus, the flexibility of hydro power, taken without reference to particular limitations and particular countries, is beginning to stand out more clearly.

There opens a new field of research, of a combined economical and technical nature, for those interested in hydro-electric development. With a given basin, which may already be developed to some extent, there are several ways of looking at the long-term future development of the remaining energy in the water, and in many countries attention is being turned to this evaluation. A single-purpose project, to provide only hydro power, can itself be looked at in at least two ways. First, its immediate benefit in additional kilowatts and kilowatt hours to the existing system; and secondly, its effect on the economics of an interconnected system with other stations of differing characteristics. These viewpoints, of course, have always been known; but with the scale of development increasing the marginal benefits which may be obtained by larger reservoir capacity in the early stages, or by very long-term planning, become increasingly significant, not only to the immediate operation of the hydro-electric and thermal stations, but to the place that nuclear power may occupy in the country's system as a whole in the years to come.

These calculations involve long-term guesses as to the trend of interest rates, and since so many projects in these days are of the size where the raising of the necessary finance (particularly in the less-developed countries) becomes an international matter, there is guidance to be had from international monetary sources on this point. Where the project, as in most cases, has more than one purpose, obviously decisions at a higher level than that of the electricity-supply administration need to be taken. If these decisions are to be based on firm foundations, then very-long-term forecasts of potential needs for irrigation, coupled to forecasts of industrial development, must be made. And thus we see the evolution of national fuel and energy policies in many countries, some as yet rudimentary; some, as in the U.S.S.R., fully developed already.

It might well be thought that a great deal of this evaluation of hydro-electric projects has already been

carried out, particularly in well-industrialised European countries. The papers at the recent World Power Conference show how much still remains to be done. For example, the United Nations Economic Commission for Europe sent in a paper in which it was said that "although there are wide differences in Europe in the economic attributes of the sites available in different regions, investigations have shown that their comparative study is fraught with great difficulty. On the other hand, relatively little work has been done on broad regional differences in European hydro resources due to year-to-year fluctuations in flow."

Even from Sweden, where it might be thought that hydro-electric development of all kinds had been refined to an extent scarcely equalled elsewhere, we learn that new methods of regional planning are being undertaken, and that it is surprising that parts of Northern Sweden are not even yet properly mapped, and that this is a bottleneck in planning, since with snow in winter and vegetation in summer, aerial photography opportunities are surprisingly scarce and there may be no single opportunity for hydro-electric planning maps to be made during the whole of an entire season.

Many World Power Conference papers stressed the difficulty of long-term forecasting of electricity demand. The British delegates admitted that demand forecasts made ten years ago had been 5–6% low, and American experience confirmed this. The general view that forecasting needed much further study and much closer linking between the technical and economic authorities adds further point to the view that a new approach to the integration of hydro-power resources, not only within the boundaries of a given country but within broad regions such as Western Europe, the North American Continent, and many other parts of the world, will play a far greater part in the technique of world energy planning than it does at present.

Those who are concerned with such matters may have thought deeply over a statement made in a Russian paper: "The possibility of interchanging various power agents (electric power, steam, hot water) and various kinds of fuels (coal, oil, gas) is rapidly increasing. The growing share of natural gas, oil and of opencast-produced cheap coal in the U.S.S.R. energy balance sheet, accompanied by long-distance pipeline transportation of gas, oil and oil products, as well as of electric power transmission and centralised heat supply, offer wide opportunities for interchanging various forms of fuel and power sources, both within districts and individual categories of consumers . . . In the U.S.S.R. complex planning of production, distribution and consumption of every kind of energy resources and of power agents has been put into effect on the basis of working out integral energy balance sheets to provide for fuel and power supply with minimum national economic expenditure." While such a statement can only be made from the background of a completely controlled economy, and may be regarded dubiously in free-enterprise countries, nevertheless the part played by energy of all kinds, and the increasingly valuable part played by the flexible partner, hydro-electric power, must inevitably lead to national planning. Those who take planning time by the forelock, may be saved the shock, in the years to come, of having the planning taken out of their hands.

Grant for Arch-Dam Research

THE Department of Scientific and Industrial Research is supporting the work of research groups in several of the English Universities who are working on problems of arch-dam design. The work is also being supported by a group of civil-engineering consultants and it will be co-ordinated by a special committee of the Institution of Civil Engineers. The investigators, who will be concerned with basic research into the stresses in dams, will use computing techniques in association with scale-model dams, and co-ordinated results will be published. The investigators are: Professor S. C. Redshaw, Birmingham University; Miss L. Chitty, Imperial College and Mr. C. Snell, University College, London; Professor D. N. de Garrs Allen, Sheffield University; and Professor P. B. Morice and Dr. J. R. Rydzewski, both of Southampton University.

India's Third Five-Year Plan

WHILE the Second Five-Year Plan of India had originally set a target of 6,900,000 kW of installed capacity to be reached by the end of the period, achievement is now likely to be 5,800,000 kW. The shortfall is mainly due to foreign exchange difficulties in the execution of schemes. Moreover, target dates for the completion of some major hydro-electric projects, such as Bhakra Nangal, Koyna and Rihand, had to be put off for other reasons.

The Third Plan target for power is tentatively proposed at 11,800,000 kW of installed capacity by 1965–66, or a little more than double the capacity India will have at the end of the Second Plan.

The exact proportion of thermal to hydro power in this quantity is not yet known but it is considered possible that the percentage of thermal power to total power generated may be stepped up from about 40 in 1960–61 to about 54 in 1965–66. The experience of the last few years in India has shown that the demand for power far outstrips generating capacity. Power shortage is at present being experienced almost everywhere, particularly in parts of Mysore, Punjab, Delhi, Orissa and the Damodar Valley Corporation area.

World Power Conference

AUSTRALIA has been chosen by the International Executive Council of the World Power Conference as the Host Country for the Sixth Plenary Meeting of the World Power Conference which will be held in Melbourne from October 20 to 26, 1962. As the Host Committee, the Australian National Committee of the World Power Conference has accepted complete responsibility for organising this Meeting. The subject of the 1962 Plenary Meeting will be "The Changing Pattern of Power," and the Technical Programme which will shortly be issued will provide for this subject being dealt with in five major Divisions:

Division I—Energy Resources, based on the World Power Conference Survey of Energy Resources and Surveys prepared by National Committees.

Division II—The Production and Amelioration of Primary Sources of Energy.

Division III—Transformation of Primary to Secondary Energy, and Transportation of Energy.

Division IV—Utilisation of Primary and Secondary Energy.

Division V—Economic Evaluation of Alternative Energy Sources.

The Technical Sessions will be followed by Post-Conference Tours of Technical and general interest throughout Australia and New Zealand.

Although considerable planning is now in hand Registration Forms and details of the General Programme will not be issued until about September 1961. Further information will be published with the issue of the Technical Programme about the end of May 1961 and full information may be obtained at any time from the Secretariat of the Australian National Committee of the World Power Conference, Box 1823-Q, G.P.O., Melbourne, C.1, Victoria.

Power Loan to Colombia

THE World Bank has made a loan equivalent to $25 million for the expansion of electric power facilities in the Cauca Valley, one of the most rapidly growing industrial and agricultural areas in Colombia. Five private banks are participating in the loan, without the World Bank's guarantee, to the extent of $559,000. The work being undertaken with the help of the loan consists of the addition of a 33,000 kW unit at the Yumbo steam plant; the construction of a new hydro-electric power plant on the Calima River with an ultimate capacity of 120,000 kW; the extension of CHIDRAL's transmission system to serve 25 towns and villages in the Cauca Valley and to interconnect it with the power system serving the Department of Caldas; and expansion of the distribution systems in Cali and in the towns and villages to be served. The Calima hydro-electric project will be located about 37 miles (60 km.) north-west of Cali; it includes the construction of a dam to create a reservoir with a useful storage capacity of 320,000 acre ft. (408 million cu. metres), a power house and associated facilities. Space will be provided in the underground power house for four generating units which will bring the Calima plant to its full capacity of 120,000 kW. The Yumbo extension should be in operation by mid-1962 and the Calima plant by 1964. Engineering for the Calima project is being carried out by three firms, Tippetts, Abbett, McCarthy, Stratton; Gibbs & Hill, of New York; and Olap-Ingenieria, of Bogotá.

Power requirements in the Cali area have grown recently at the rate of about 16% a year and are expected to continue at this rate for the next few years.

American 750 kV Test Line

AMERICAN Electric Power Service Corporation and Westinghouse Electric Corporation are to construct and operate a 750 kV test transmission line in the United States as a joint project. The country's electric utilities now operate their transmission systems at a maximum of 345 kV, and previous experimental lines in the United States have been operated at a maximum of 500 kV. The line will be energised in late 1960 or early 1961, and it is expected that the tests will require three to five years to complete. The line will be made up of three sections so that the different kinds of conductor can be tested simultaneously in the same environment. The results will be processed through automatic data-logging computers and recording instruments.

Other companies that are participating in the project, and the equipment or materials which they are supplying include: Kaiser Aluminum & Chemical Corporation—conductor; Lapp Insulator Company, Inc., and Ohio Brass Company—insulators and hardware; Thomas and Betts Company, Inc.—connnectors; and American Bridge Division of United States Steel Corporation—towers.

Hungarian Hydraulics Conference

A CONFERENCE on river hydraulics and the hydraulics of infiltration is being organised by the Hungarian Society of Hydrology and the Research Institute for Water Resources under the auspices of the Hungarian Academy of Sciences. It will be held in Budapest on September 5–10, 1960, and the president of the Organising Committee is Ihrig Dénes, Scientific Chief Research Institute for Water Resources, Budapest VIII, Rákoczi-ut 41, Hungary.

Australian Surveying Team in Indo-China

AUSTRALIAN experts will help a United Nations project to harness the Mekong river in Indo-China. Surveyors of Snowy Mountains Authority of Australia will begin work in October to find potential dam sites. The leader of the survey team, Mr. Falconer, is now in Thailand for preliminary discussions. He will return to Australia in a few weeks and go back in October with a team of ten experts.

The Mekong scheme envisages the construction of eight hydro-electric and multi-purpose projects along the Mekong river to benefit 70 million people in Laos, Thailand, Cambodia and South Vietnam. Australia will make a geological survey under the Colombo Plan at a cost of more than £A180,000. Ten other countries are contributing.

IAHR Belgrade Congress

THE next convention of the International Association for Hydraulic Research will be held at Belgrade on September 3–7, 1961. Papers are invited on the following topics: "The Effect of Turbulence on Hydraulic Structures", "Mechanics of Groundwater Flow", "Hydraulic Problems for Computers", "Modifications of Natural Streams by Engineering Structures". In addition to the official sessions on the foregoing subjects, two seminars will be held on "Hydraulics of Small Structures in Irrigation and Drainage" and "Fundamental Hydrodynamics of Free Surface Flow and of Unsteady Flow".

The secretary of the Organising Committee for this, the Ninth General Meeting of the Association, is Ing. Mihailo Vojinović, Hydraulička laboratorija-Avala, Beli Potok, srez beogradski, Yugoslavia.

Smith Mountain Generator Contract

AMERICAN Electric Power Service Corporation, New York, has awarded a contract to Elliott Company, Ridgeway, Pennsylvania, for two 25 MVA 138·5 r.p.m. waterwheel generators. The units will be installed at the Lower Development plant of the Smith Mountain project on the Roanoke River near Alta Vista, Virginia. Appalachian Power Company is undertaking the project, based on engineering designs of the American Electric Power Service Corporation. Both generators will have outdoor enclosures and

umbrella-type construction. They will be driven by Baldwin fixed-blade turbines, and the expected operation date is 1962.

Tokke II and III Sanctioned

THE further development of the Tokke-Vinje hydro-electric power project in the county of Telemark, in Central Norway, has been sanctioned by the Storting. It includes the building of two more power stations, Tokke II and Tokke III with a planned capacity of 300 and 110 MW respectively. The total cost is estimated to be £21,200,000, and it is hoped that a substantial part of this can be financed through a loan from the World Bank. The work is planned to be concluded in 1965. The Storting further sanctioned the building of main transmission lines from the Tokke stations, and also a main line from Skjeberg in South-East Norway to the Swedish border intended for power export.

Fort Rosebery Hydro-Electric Scheme

THE first stage of a hydro-electric scheme at Fort Rosebery, Northern Rhodesia, has been completed by the Laing Group of Companies. This comprises a reinforced-concrete weir 360 ft. long and 15 ft high carrying a 30 ft. wide reinforced-concrete road bridge across the Luongo River near the Musondo Falls. All materials and a large proportion of the labour force for this work were transported from the Rhodesian Copper Belt some 135 miles distant.

Correspondence

Hydro Power in Canada

To the Editor, WATER POWER

In connection with the article "Hydro Power in Canada," by Mr. H. G. Cochrane, published in your June issue, I should like to correct some serious misstatements which have been made under the subheading "Peace River May Be Deferred."

The first paragraph under this subheading states that the storage created by our Peace River dam would be over 30 million acre-ft. It is correct that it is over this figure, but the storage is actually 88 million acre-ft., or almost three times the amount the author mentions. He goes on to state that "Early this year, two U.S. power companies in the Pacific States turned down offers of power from the Peace River at a quoted price of 5½ mills per kWh. W. C. Mainwaring, President of the Peace River Power Co., stated the timetable for the initial stage had been set back two years as a result."

This is a complete misrepresentation of fact. We have not quoted prices to anyone in the United States and we decided to bring in first generation in 1968 instead of 1966 for an entirely different reason.

We realised last year that it would take some time for the new National Energy Board to set up an organisation and deal with applications for export, and had we brought in our first generation in 1966 it would have been necessary to export about one-third of our first generation. By delaying first generation two years the incremental load growth in British Columbia is sufficient to take up the amount of energy that we might have exported and makes our project entirely feasible on the basis of energy sales in British Columbia without any export. Our decision to bring in first generation in 1968 had nothing whatever to do with the price we might wish to get for energy if we did export any.

In the same paragraph this statement appears: "It was recently predicted at Victoria, however, that the Wenner-Gren interests would probably drop the project this year and forfeit their half-million dollar performance bond, as well as the $5 million spent on surveys." I believe some politician did make some such statement, but no one took it seriously, and it is far from the facts.

Peace River Power Development Company took over an assignment of Wenner-Gren's power agreement with the Provincial Government of British Columbia in November, 1958, and it is our responsibility to carry out the terms of that agreement, which we have complied with up to the present time in every respect, and fully intend to do in the future. Wenner-Gren had a separate agreement in connection with the construction of a railway in British Columbia, and, as recently announced by The Honourable W. A. C. Bennett, Premier of British Columbia, Wenner-Gren B.C. Development Co. Ltd. has not only lived up to its agreements with the British Columbia Government, they have also gone far beyond the terms of the agreement.

W. C. MAINWARING
President,
Peace River Power Development Co. Ltd.,
Vancouver, B.C.

Mr. Mainwaring's letter has been referred to Mr. Cochrane, who replies as follows:—

I wish to thank Mr. W. C. Mainwaring for drawing attention to "mis-statements" contained in my article on "Hydro Power in Canada" in your issue of June 1960. The 30 million acre-ft. of storage mentioned as being created by the Peace River dam should have read 80 million acre-ft., and was due to an error in typing.

In the last paragraph of Col. 2, page 227, continued overpage, the first eight lines were taken from a report written by the Vancouver correspondent of *The Montreal Gazette* and published in the January 28, 1960, issue of that paper, while the last five lines were from a report appearing in the February 18, 1960, issue of the *Engineering News-Record* on page 34.

More recent Press reports, following the mailing of the article early in March, have indicated that the Province is granting a certificate of "public convenience and necessity" for the project and that it is satisfied the scheme is "entirely feasible from an engineering standpoint."

H. G. COCHRANE, M.E.I.C.

We have checked Mr. Cochrane's references and would confirm that the statements to which Mr. Mainwaring objects were contained in the two papers quoted and were accurately reproduced in Mr. Cochrane's article. It is evident, therefore, that Mr. Cochrane used this information in good faith, but we are glad that his article has afforded Mr. Mainwaring an opportunity of placing the true facts on record.—THE EDITOR.

Fig. 1. The Niagara generating station seen from across the Niagara River

The American Niagara Power Project

An account is given of the constructional work now in progress on the American side of the Niagara Falls

By IAN B. MACKINTOSH, M.A., A.M.I.C.E., M.ASCE.*

SEVERAL small hydro-electric plants were built at Niagara early this century which utilised only a fraction of the power potential of this site. Further development was hampered by the need to reach an international agreement between the United States and Canada, as the Niagara River forms the boundary between the two countries, and it was decided to protect the Falls as a natural spectacle. A treaty was signed in 1950 which fixed the minimum amount of water for scenic purposes which must be allowed to pass over the Falls at various times and divided the surplus water for diversion between the two countries. In addition, Canada was to build a control structure which projects out from the Canadian shore, and America was to carry out remedial works on the crest of the Falls, both with a view to preserving the same scenic effect even though less water would be passing over the Falls.

Canada went ahead immediately in 1950 and built her share of the power development, and in 1954 the Sir Adam Beck Generating Station No. 2 was dedicated by H.R.H. the Duchess of Kent. A political dispute in the United States as to whether the project should be built by private interests or by the State or Federal Government delayed the start of the development on the American side until February 1958, when the first contracts were let by the Power Authority of the State of New York, who will own and operate the plant.

The American development is very similar to the Canadian one in general outline, and this has already been described in WATER POWER[2]. The topography of the site is more favourable to the American development since the headrace conduits cut across the inside of the sweep of the niagara River, and are therefore shorter than the Canadian ones which follow the outside. On the other hand, the American conduits pass through a more heavily built-up area. Another difference is that the American development provides a much bigger pumped-storage facility than the Canadian.

The main features of the American Niagara project are shown in Fig. 2. The Niagara and Tuscarora power plants will have a combined total capacity of 2,190 MW and the total project costs will be $720 million. The head utilised is 314 ft., which is only 12 ft. less than the difference in water levels between

* Senior Engineer, Taylor Woodrow Construction Limited, London.

Lake Erie and Lake Ontario. The flow of the Niagara River is very steady at about 200,000 cusecs and the New American power plants' share of this will be approximately 50,000 cusecs during the daylight hours of the tourist season and 75,000 cusecs at other times. The Tuscarora plant, which is the pumped-storage element, produces 240 MW and the water which it stores up at night will be passed through the main Niagara plant to augment the limited daytime diversions from the river.

Main Contractors

This report describes parts of the works which are at present under way by a construction force of 8,000 men. The civil-engineering works are divided into six main contracts, details of which are given in Table I.

Niagara Generating Plant

This main plant is housed in a power house 1,840 ft. long by 580 ft. wide and 376 ft. high and requires 1,104,000 cu. yd. of concrete. It will accommodate thirteen 150 MW generators and consists basically of an intake structure at the top of the gorge and generating equipment at the bottom connected by 24 ft. diameter penstocks each 462 ft. long. The gravity-dam intake structure is about 1,100 ft. long and contains trashracks, emergency stoplog grooves and vertical-lift intake gates; there is also a 90 ton travelling gantry for handling the various gates. The generators will be mounted below the power-house deck under removable hatch covers, and a 630 ton travelling gantry crane will handle the generator parts.

A vertical grout curtain is to be placed along the length of the power-plant forebay just in front of the intakes to the penstocks. Drainage galleries will be driven into the rock to draw off any seepage through the grout curtain. The rock mass in front of the curtain will act as a gravity dam to carry the full hydrostatic thrust on the grout curtain.

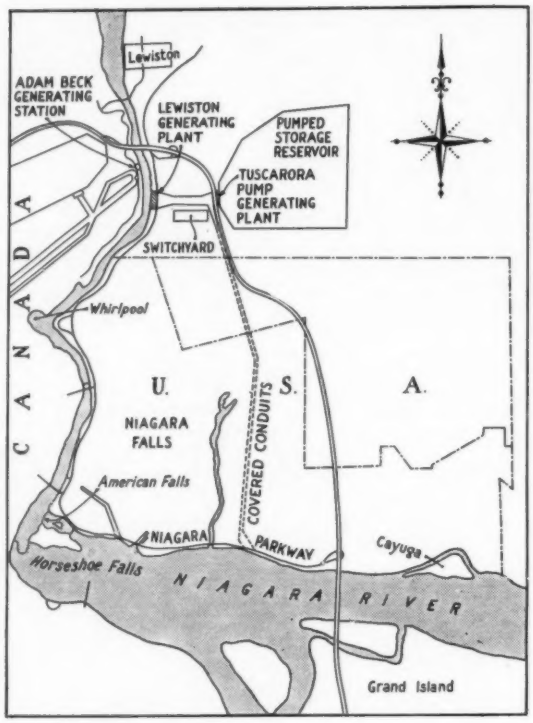


Fig. 2. Location map of American Niagara power project

TABLE I.—MAIN CONTRACTS OF NIAGARA PROJECT

Work section	Contractor	Contract sum	Length of conduit	Excavation	Concrete	Earth and rockfill
		$	ft.	cu. yd.	cu. yd.	cu. yd.
Niagara Generating Plant	Merritt-Chapman & Scott Corporation	98 m.	—	9·6 m.	1·1 m.	—
Work Section No. 1 Waterways (including intake)	Merritt-Chapman & Scott Corporation	66 m.	8,000	7·4 m.	0·67 m.	—
Work Section No. 2 Waterways	Balf Co.—Savin Bros. & Winkelman Co.	37 m.	9,000	5·1 m.	0·61 m.	—
Work Section No. 3 Waterways	Gull Contracting—Defelice & Son	30 m.	5,500	4·6 m.	0·45 m.	—
Work Section No. 4 Waterways and Reservoir (including aggregate plant)	Kiewit—M.K.—Walsh—Perini	32 m.	4,000	9·6 m.	—	8·75 m.
Tuscarora Pump Generating Plant	Arundel—Dixon	40 m.	—	2·6 m.	0·67 m.	—
	Totals ...	303 m.	26,500	38·9 m.	3·5 m.	8·75 m.

The contractor is using Cooke Bros. 30 ton bottom-dump trailers drawn by Mack B-62 trucks to haul the aggregates to his plant. Before the aggregates enter the batching plant they pass through a tunnel 300 to 400 ft. long in which they can be sprayed with refrigerated water. An aggregate storage area at the top of the gorge supplies aggregates to the upper batching plant and also (by means of a downward-sloping conveyor belt) to the lower batching plant which is at the level of the generator floor. The aggregate reclaim tunnel is 9 ft. in diameter and houses a 36 in. conveyor belt. Syntron vibrating gates are used to feed sand on to the belt.

Both the upper and the lower batching plants are Johnson fully automatic plants with three 4 cu. yd. tilt-type mixers. The cement is delivered in rail cars from Buffalo and there are two silos for Portland cement with a combined capacity of 12,000 barrels. The nominal capacity of a single plant is 240 cu. yd. per hour but the best output achieved in one 8-hour shift is 1,185 cu. yd. Level with the top of the gorge is a steel trestle 40 ft. wide on which are mounted three American Hoist & Derrick 50 ton whirley cranes with 150 ft. booms. These handle the concrete produced by the upper batching plant. At the lower level there is another steel trestle over the lower part of the penstocks and this carries two more whirley cranes. Finally there are another two whirley cranes located in the bottom on a track which runs just outside the draft tubes, and inside the rockfill cofferdam which traverses the river bank. Concrete is handled in Garbro 4 cu. yd. buckets. The buckets are carried to the whirley's on rail-mounted cars which take four buckets, and the car is drawn by a Plymouth Torquomotive 180 h.p. diesel locomotive.

Merritt-Chapman & Scott have a force of 2,000 to 2,200 men on this contract, which started in February 1958. The concrete work was 30% complete by mid 1959 and will be 85% complete by the end of 1960. Final completion is not until 1962.

Tuscarora Aggregate Plant

All the aggregates for the 3,500,000 cu. yd. of concrete required in the entire project are being produced at one plant as part of the P.K.M.K. combine's contract. They are obliged to meet the requirements of all other contractors and the contract calls for the supply of the aggregates at overhead bins; each contractor takes delivery of the aggregates he needs at the Tuscarora plant and hauls them to his own job site. This pooling of the means of aggregate production was used successfully on the American part of the St. Lawrence Seaway, and has advantages where there are several contractors engaged on one project, and where space for the installation of aggregate plants is limited.

The plant consists of two parallel lines of identical equipment, each having a capacity of 1,000 tons of material per hour or a total of 2,000 tons per hour. The plant will produce a total of 10,400,000 tons of aggregate, sand and embankment filter material for the project. The peak demand is 30,000 tons per day.

The primary crushers are Cedar Rapids 53 in. by 60 in. double-impeller impact crushers, and these crush 3 ft. boulders to 7 in. size and under; the secondary crushers are 5½ ft. Symons standard cone crushers and they crush down to 3 in. size and under; and the tertiary crushers which reduce the rock to 1½ in. size and under, are 7 ft. Symons shorthead cone crushers. At each crusher building a double-deck screen sorts the materials, and part is taken off into stockpiles by conveyor. Part of the ¾ in. and under size goes into the two Allis-Chalmers 9½ ft. by 13 ft. rod mills to be crushed to under No. 4 mesh size and thence into two Eagle screw classifiers which remove excess fines. The materials end up in five stockpiles in a single line which have a total capacity of 570,000 tons. Under the three stockpiles there are three parallel 6 ft. by 7 ft. reclaim tunnels made from Commercial's tunnel liners built over a concrete invert, through each of which runs a 36 in. conveyor belt. These belts feed three identical aggregate shipping bins from which the other contractors draw their materials.

Water for washing is obtained from a 28 acre settling basin nearby from which 65 million gallons of water are recirculated at 15,000 g.p.m. by Allis-Chalmers and Fairbanks-Morse pumps. The excavated rock is hauled to the plant by a fleet of 30 Easton side-dump wagons of 21 cu. yd. capacity powered by Euclid four-wheel rubber-tyred tractors. Although these trucks are very much more expensive than Euclid rear dumps of the same capacity they pay off by virtue of the very much shorter time they take to unload.

The installation, the estimated capital cost of which is $6 million, was designed for the combine by John F. Misenor, a consulting engineer. The plant is operated by a total of 150 men, including maintenance men working on three eight-hour shifts. The plant

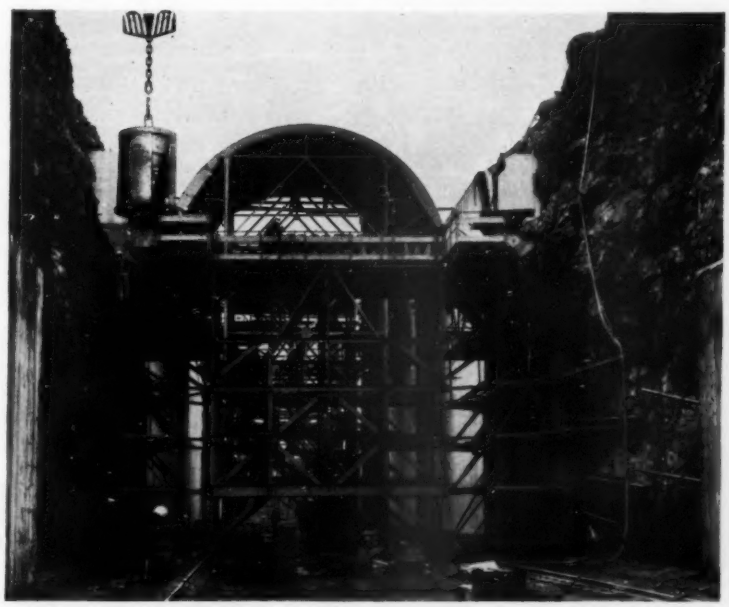


Fig. 3. Travelling steel form for concreting the water conduits

started operating late in 1958 and has three years to run. Concrete operations on most project work sections will be shut down during the winter and aggregate production will also be shut down in this period. But there will be a large enough stockpile of aggregate available for any contractor wishing to do winter concreting.

Tuscarora Reservoir

The reservoir is formed by a rockfill dyke with an impervious centrol core. The dyke averages 55 ft. in height and has a base width of 245 ft. and a crest width of 40 ft.; the total length of the dyke is 5½ miles. There is only just enough clay available for the impervious core and it comes partly from the forebay excavation and partly from the dyke excavation. The dyke is built in three operations: first, the clay is compacted in 6 in. layers, using sheepsfoot rollers, and this part of the fill is raised 3 ft. at a time; secondly, the sides of the clay are trimmed to a 2 vertical to 1 horizontal slope and the filter zones are then placed; thirdly, the rockfill section is brought up level with the remainder. To avoid interference it is necessary to have three work sections in operation, and each requires about 3,000 ft. of space. The clay is moved by scrapers and the rock by the Easton side dumps. During the winter from the end of November to April the embankment operations will be shut down.

The bulk of the grouting of the dyke foundation will be done by drilling through the overburden. When the overburden has been removed the top 5 ft. will be regrouted and tested. It is estimated that 10,000 tons of Portland cement will be required for preventing excessive seepage from the reservoir.

Forebay Excavation

The excavation for the forebay is a cut 110 ft. deep and 500 ft. wide. Line drilling has been specified for the walls of the cut as it is to be left unlined. The method adopted is cushion blasting using an 8 in. diameter hole, and is similar to that used on the Canadian Niagara project. This line drilling enables the overbreak to be kept down to 3 to 4 in.

The method of wall trimming adopted on the Canadian project was developed after considerable experimenting. Percussion drills put down 6¼ in. and rotary drills 6¾ in. holes to 30 to 35 ft. deep placed at 5 ft. intervals, and a 5 × 6 ft. drilling pattern was used for the holes a short distance from the wall. Then three 1½ in. wagon-drill holes were drilled in each 5 ft. space between the main holes along the trim line as shown in Fig. 5. Of the wagon-drill holes only the centre one was loaded and to about 4 ft. from the collar. In addition the main holes were "cushion-blasted" by taping the charge to a length of detonating fuse. In this case the string of 1⅛ × 8 in. cartridges was lowered into the whole on the side farthest from the wall and the remaining space was filled with screenings.

The rock excavation is being carried out by drilling 4 in. diameter holes 25 ft. deep using Gardner Denver track drills and blasting well in advance of loading.

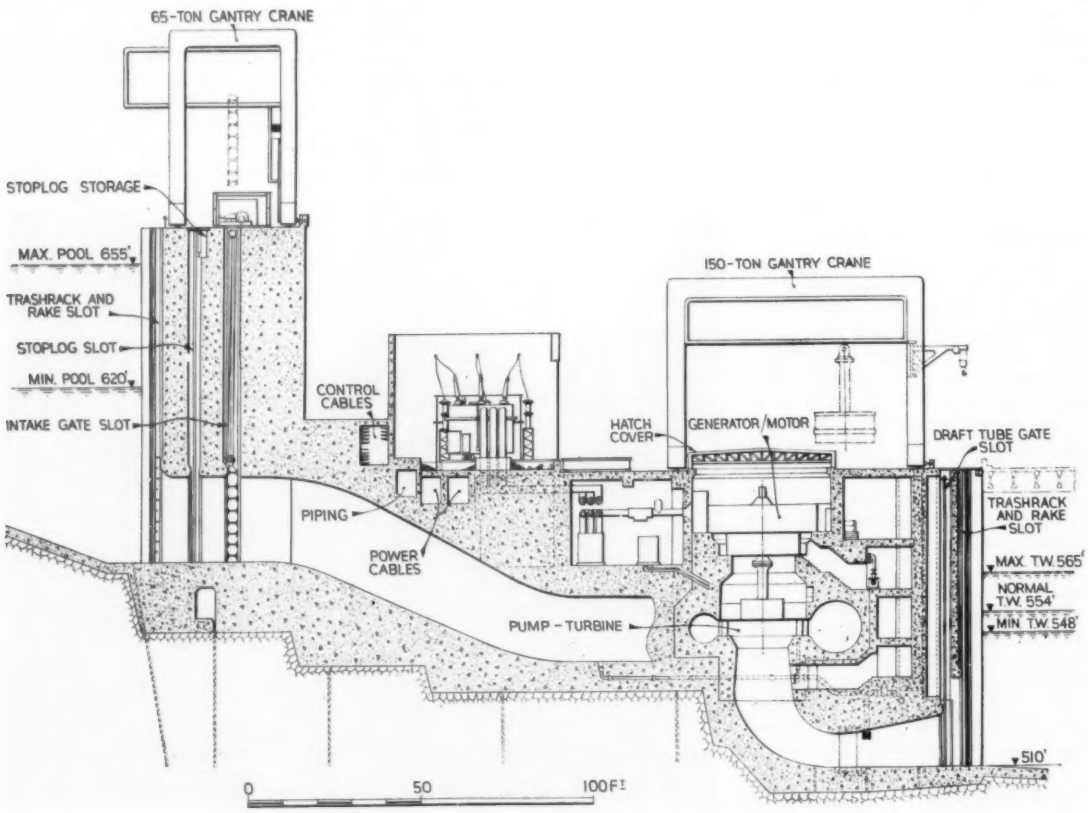


Fig. 4. Typical cross-section across the Tuscarora power plant

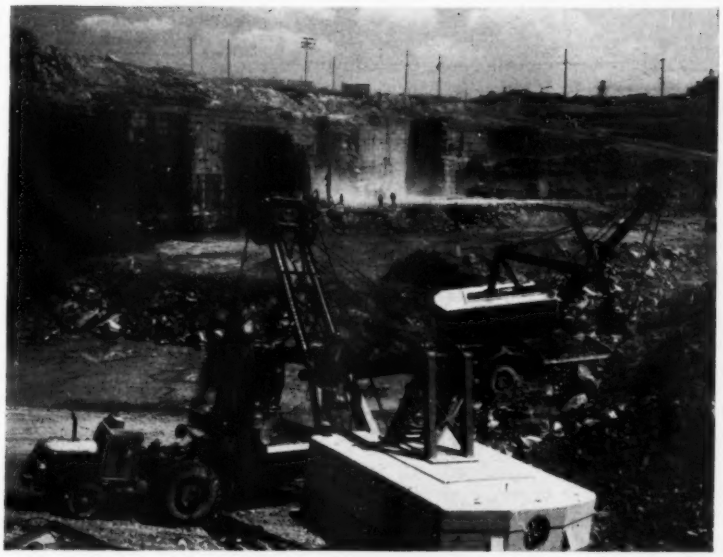


Fig. 5. Rock excavation in forebay area showing the clean vertical walls achieved by line drilling

The material is loaded into the 30 Easton 21 cu. yd. side-dump trucks by four 150B electric 6 cu. yd. face shovels whose combined output is 1,000 cu. yd. per hour.

The hauling distance is ¾ mile to the aggregate plant and 2 miles to the dyke, with a maximum adverse grade of 15%. P.K.M.K. have 25 D8 Caterpillar tractors and five motor patrol graders on this contract.

Tuscarora Pump Generating Plant

This concrete power-plant structure, which forms part of the reservoir dyke, is 993 ft. long and 162 ft. high. It will house 12 modified Francis-type pump-turbines, which will each deliver, as a pump 3,400 cusecs at 85 ft. net head, and as a turbine-generator 20 MW at 75 ft. net head.

The structure has 670,000 cu. yd. of concrete in it and is served by a Johnson automatic batching plant with four 2 cu. yd. tilt-type mixers; the nominal capacity is 160 cu. yd. per hour but its actual capacity is 140 cu. yd. per hour. The plant has storage silos for 7,080 barrels of Portland cement and 616 barrels of natural cement. The 6 in. concrete mix has 590 lb. Portland cement and 100 natural cement; the 3 in. mix, 680 lb. Portland cement and 100 lb. natural cement; and the 1½ in. mix, 890 lb. Portland cement and 100 lb. natural cement; to give 2 cu. yards of concrete in each case. This concrete plant is operated by a crew of seven men.

The concrete is placed in the work by four whirley cranes, two located on travelling tracks on an upper steel trestle, and two located on travelling tracks at ground level on the downstream side. Concrete is fed to the whirleys by three transfer cars which each carry four 2 cu. yd. Garbro buckets; these are loaded underneath the batching plant, and the bottom opening gates are actuated by coupling up an air hose to the bucket when it reaches the point of placing.

A travelling elevating conveyor, which moves on rails, is used as a stacker for the aggregate stockpiles. This is fed from a horizontal conveyor parallel to the stockpiles on which a carriage runs up and down enabling the delivery point to be varied. Materials of one size only would be delivered for, say, a four-hour period to minimise movements of the stacker. The aggregates are hauled to the plant by bottom-dump Mack truck trailers.

Water Conduits

The conduits which carry the water from the Niagara River above the Falls to the Niagara power plant 4½ miles away are designed as flexible structures to accommodate possible movement of the rock through which the conduits are built. The key to the design is the use of a three-hinged arch, so that the conduits can take the rock squeeze from one or both sides.

There will be two 22,000 ft. long covered conduits each 46 ft. wide by 66 ft. high with their centrelines 200 ft. apart. The conduits have three independent elements: the side walls, the bottom slab and the

Fig. 6. Aggregate stockpiles of the 2,000 tons per hour Tuscarora aggregate plant

three-hinged arch. The arch loads will be carried directly to the rock through the arch abutments. The arch design used is strong enough to carry the greatest height of fill, which is 80 ft. The arch has a 23 ft. radius and is varied in depth from 4·5 ft. at the crown to 6 ft. at the abutments. The semi-circular hinges at the abutments are 15 in. radius and that at the crown is 2 in. radius. Compressible filler material will be placed in the hinges, and this consists of a coal-tar coating. The joints on either side of the hinge are packed with a 1 in. filler of plastic foam. In addition, a plate of sheet lead is laid over the complete surface. The side walls and bottom slab, provided to reduce head losses, are 2 ft. 6 in. design thickness and are tied to the rock by anchor bolts. Squeeze mostly takes place soon after excavation, so the specification provides a 60 day wait between excavation and placing the arch concrete, and a 30 day wait for the side walls and bottom slab, to allow movements to take place.

Intake Structure

The design of the river intakes for the conduits has been subject to extensive model testing, which was carried out in the hydraulic laboratory of the Ontario Hydro-Electric Power Commission, who already had a model of the Niagara River available. By design modifications head losses have been reduced from 4 ft. to 2½ ft. There will be two submerged-tube-type structures, each 700 ft. long, with entry ports, 11 ft. 8 in. wide and 19 ft. in average height, in the vertical face, and with a sill about 40 ft. below normal river level.

The intake structure is being built in a cofferdam reaching out into the river. This is a clay dyke with a steel sheet-pile cut-off driven in the dyke with a heavy rockfill dumped on the upstream face. At the corners of the cofferdam a number of 35 ft. diameter cells of M.P.10 section steel-sheet piling were used to enable the cofferdam to resist scour at these points. The complete perimeter of the site, including the land side, will be grouted to an average depth of 40 ft. to prevent seepage of ground water into the excavation through very porous underlying strata. The complete cofferdam was constructed in about four months.

Merritt-Chapman & Scott Corporation, as was seen from Table I, have the $66 million contract for the intake and section 1 of the waterways. This contract is being managed entirely independently from that for the Niagara generating plant four miles away. M.C. & S. have the following plant on this contract.

4 Lima 2400 6 cu. yd. excavators
3 Marion 111M 4 cu. yd. excavators
1 Marion 93M 3 cu yd. excavator
1 Manitowoc 4500 45 ton crane
2 Manitowoc 3500 35 ton cranes
65 Euc. or I.H. 20 cu. yd. rear-dump trucks
10 Mack 10 cu. yd. rear-dump trucks
1 I-R line drilling rig
2 G.D. 143 air track drills
2 G.D. 123 air track drills
1 4-4 cu. yd. automatic batching plant.

The concrete is hauled on Euclid flat-bed trucks which carry two 4 cu. yd. Garbro buckets. The rock faces are drilled with 3 in. holes at 9 in. centres and the resulting overbreak is about 6 in..

Dredging to the extent of 1,700,000 cu. yd. is required in the river just in front of the intakes, and this is being carried out by a M.C. & S. 10 cu. yd. bucket dredger. About 400,000 cu. yd. has been moved in three months' work. The material is loaded into bottom-dumping scows attended on by three tugs, and is disposed in shallow water to reclaim ground for the Niagara Parkway. The dredging is being carried out by a total crew of 30 men working in three shifts.

Acknowledgments

The writer wishes to extend his thanks to the following for their help during his visit: Mr. Lee Rowe, Peter Kiewit's Project Manager; Mr. Herbert Booth, Merritt-Chapman & Scott's Project Manager on the Niagara generating station, and Mr. Duke Ghrovick, Merritt-Chapman & Scott's Project Engineer on the Intake and Work Section No. 1, and also to Mr. William Chapin, General Manager and Chief Engineer of the Power Authority of the State of New York. The Authority's Project Manager is Mr. William H. Latham and the Resident Engineer for the consulting engineers, Uhl, Hall and Rich, is Mr. John P. Ottesen.

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[1] "Niagara Project: Big Job, Big Problems," *Engineering News-Record*, February 26, 1959, p. 30.
[2] HEARN, RICHARD L., "Sir Adam Beck—Niagara G.S. No. 2," WATER POWER, July 1956, p. 246.
[3] RICE, H. R., "More Canadian Kilowatts at Niagara," *Compressed Air Magazine*, August and September 1953, p 210.
[4] RICE, H. R., "Ontario Hydro Project at Niagara Falls," *Canadian Mining Journal*, May and June 1953, p. 63.

Instrument Manufacturers' Merger. Subject to the approval of the respective shareholders, a merger is to take place between The Cambridge Instrument Co. Ltd. and Electronic Instruments Limited. The offer is on a share exchange basis of seven Cambridge 5s. shares (now standing at 25s. 6d.) for three Electronic Instruments £1 shares. This merger has been mutually sought, and is conceived as a partnership between two firms with similar aims and complementary interests. The Cambridge Instrument Co. Ltd. has been in existence for 79 years and makes precision instruments for all purposes from medical work to nuclear power stations. Electronic Instruments Limited, of Richmond, Surrey, was founded 15 years ago and specialises on the design and production of instruments that are new in their respective fields. Each of the two companies will continue to operate under its own name, but an interchange of directors will ensure full collaboration between the two firms.

Compressed-Air Firm's Take-Over Bid. Atlas Copco AB, of Stockholm, have made an offer for the control of Svenska Diamantberg Borrnings AB, a Swedish company with overseas associates which specialises in drilling operations for testing soil, rock strata, mines and ore deposits. Svenska Diamantberg Borrnings AB shareholders are offered five Atlas Copco shares for one S.D.B. share, plus Sw. Kr. 30 in cash. For the purpose of the offer, Atlas Copco AB share capital is being increased—subject to the shareholder's approval—by the issue of 562,500 shares at a par value of Sw. Kr. 25 per share.

Corrosion Prevention. A four-page coloured leaflet from Expandite Limited, entitled "Expandite Cut the Cost of Corrosion", refers to Metagalv zinc-rich brush-applied galvanising coating, Expaflex brush-applied chlorinated-rubber coating, and Gewi protective tape.

Symposium on Computers in Civil Engineering

A brief account is given of a symposium on the application of computers to civil engineering calculations held at the Northampton College of Advanced Technology, London

IN our leading editorial, "The Computer—The Designer's New Tool" (WATER POWER, April 1960), we referred to a London college which was actually giving courses on computer techniques and programming. This college, the Northampton College of Advanced Technology, St. John Street, London, E.C.1, held a symposium in June on "The Application of Electronic Digital Computers to Civil Engineering Calculations." where three papers were presented and discussed. The scope of the symposium was to outline the value and merit of the computer in civil engineering, its present and future roles, some of the problems attempted and the experiences gained by the computer department of the college, and finally the economics of using the computer.

Present and Future Computers for Civil-Engineering Problems. *E. S. Coates, B.Sc. (Hons.), Grad. R.Ae.S.* This paper began with the research upon and the production stages of present-day computers, and then gave a forecast of future developments based on the present trends of design and requirements. It was expected that future computers would show a marked improvement in detail design rather than a change in fundamentals. Computers generally would have bigger stores, and with the overall use of transistors, the improvements would be in size reduction, longer life compared with vacuum tubes, and in the elimination of heating problems. Future computers were envisaged to incorporate a means of digital-analogue conversion and vice-versa.

Structural problems covering non-linear analysis should be considered and arranged with the computer in mind, as in Dr. R. K. Livesely's matrix-displacement method in which the equations of joint equilibrium of a structure were constructed systematically from load-displacement equations of the individual members and analysed into stiffness matrices. This method has now been extended to include elastic instability due to bending effects of axial forces in the members.

To solve flows in a pipe network by the Hardy-Cross method, where the head loss H is a function of the discharge Q, $[H=kQ^{1\cdot85}]$, a computer should prove a great asset. It could also be applied to analyse the stresses in the pipe network and to solve water-hammer problems. Furthermore, certain surge problems have been adapted for solution on the IBM 650 computer such as that on the Oahe*† surge system, so that now there is available a machine programme for the IBM 650 for solving load-rejection and full-load demand problems of a surge system comparable to the Oahe project in one to two hours of machine time per case.

The degree of accuracy in the results was then discussed. The National Physical Laboratory has made an attempt to improve the solutions by simultaneous equations and hence solve any structural problems. In strain-energy methods, where the answer is the small difference of two very large quantities, a fine degree of accuracy is essential and it is here that the computer is most useful as it can provide more digits than can be easily obtained with manual methods. The computer is decisively quicker and consistent. It was mentioned that the computer should not only be used to obtain a quick result but be used to improve the quality of design by making comparative studies of a large number of alternatives in a short time.

Experiences in Teaching Civil Engineers to Use a Computer. *L. T. G. Clarke, M.Sc., and N. P. Roberts, B.Sc. (Eng.), A.M.I.C.E.* The authors, the former being in charge of the computing section and the latter a member of the Civil and Mechanical Engineering Department, both at the Northampton College of Advanced Technology, introduce a new idea in teaching civil engineers to use and to solve individual problems on the computers available at the college—viz. Ferranti Pegasus digital computer and an Elliott G-Pac analogue computer. They encourage the graduate engineers in the various firms to bring the problems with which they are confronted to the college where an exchange of ideas may take place and the type of approach discussed for the benefit of staff and engineers present, and finally to programme and solve the problem. This method not only teaches different techniques to the civil engineers who are attending the computer courses, but an industrial problem is solved as well. This was illustrated by Mr. J. D. Harrison (Metropolitan Water Board) when he discussed a programme he had worked out during the course of a trial example involving pipe-network flows and peak demands to determine whether the pressures in the mains were adequate to maintain the flows. It was then hoped that industry would co-operate and encourage this method.

The paper then outlined the procedures necessary in programming and development of such problems as: the mathematics, the approach, arranging the numerical techniques as a flow diagram, re-examination of the problem to determine whether a better approach could be found, range of data, conversion into the computer, and finally the output.

In many cases, a programme is used only once, but if it is to be used often, then it would be better to produce an efficient programme incorporating all the possible short-cuts and thus save valuable computer time. Two methods of solution were mentioned under

* "Hydraulic Analysis of Surge Tanks by Digital Computer." Proceedings of A.S.C.E., hydraulics section, April 1959.

† The Oahe project, consisting of the Oahe dam and multipurpose reservoirs, is on the Missouri river, U.S.A. There are seven Francis units, each of 85 MW capacity.

which most civil-engineering problems were classified: relaxation methods included pipeflow networks and dams whereas rigorous methods included moment distribution, bridges, cut and fill, staircases, cooling towers, piles and variable-section beams.

Economics of Using Computers for Civil-Engineering Calculations. *B. M. Evans, A.M.I.C.E., A.M.I.Struct.E.* After having briefly described the difference between analogue and digital computers, the paper detailed the stages of preparing a programme. The automatic coding system or autocode was recommended for problems of the "once only" type due to ease of programming and the relatively cheap initial costs.

The factors which must be taken into account to assess the time cost of using a computer were:—

(a) Cost to train engineers as programmers. To write a programme using normal computing programming methods requires a training time of at least three weeks whereas programme preparation can cost between £200 and £300. But these costs are economic for a programme that is flexible in character and with unlimited application in the particular subject. The simpler autocode method of programming usually requires 2–3 days of training so that training costs are down to about £5 5s., but where machine time is included the cost will be higher. The charges of using the computer vary between £50–£75 per hour, but a most complicated type of engineering calculation that is normally carried out in a design office should not take more than five to ten minutes of computer time, that is, costing £7–£14.

(b) Time spent in preparation and checking a programme. A programme must be correct and it should be checked and tested, but these costs hardly ever exceed £50.

(c) Operating time of a programme on a computer. The costs that have been mentioned were based on the assumption that the computer had been hired. Some organisations already possessed a computer and hence a reappraisal of costs would be necessary as computer staff would then be available to assist in programming and operation. However, computer service centres run by computer manufacturers offer their services at different charges depending on the type of machine used. The Structural Computing Service of Manchester College of Technology have the following scale based on the Ferranti Mercury computer using the Livesley programme:—

subframes	charges
1	£5 per loading condition
2	£10 ,, ,, ,,
3	£16 ,, ,, ,,
4	£23 ,, ,, ,,
5	£31 ,, ,, ,,
6	£42 ,, ,, ,,
7	£54 ,, ,, ,,

It was also stated during the discussion that followed that the IBM computing services have these charges:—

£27 10s. per hour on the IBM 650
£240 per hour on the IBM 704
£400 per hour on the IBM 709

It should be mentioned that the IBM 704 and IBM 709 are very fast machines of the order of four to five times faster than the Ferranti Mercury. The cost of running a computer programme is small compared with the cost of a project. In the case of determining the volume of an empty reservoir involving some 1,450 spot heights, the computer time was about four minutes with about an hour for data-tape preparation.

On the other hand, the programme services offered by LEO Computers Limited, Hartree House, Queensway, London, W.2, are slightly different. Here, a programming fee is charged of £2–£4 per hour depending on the programmer employed and the novelty of the problem, to analyse the problem and to set it into a programme. Once this has been done, the programme, which is now owned by the clients, is fed into the LEO II/5 computer and a charge of £50–£60 per hour of computer running time is made. This charge includes the supply of free tape and data input and output facilities, the latter utilising an output printer of some 300 lines per minute. This becomes most useful when there is a copious amount of output data.

The Short Brothers and Harland Limited, Montgomery Road, Castlereagh, Belfast, Ireland, general-purpose computer has been used to study the energy storage by pumping water from a lake at one level to another at a higher level during off-peak periods. This was undertaken for the Swedish State Power Board.

An analysis of a hydro-electric system has been worked out by Elliott Automation, Elstree Way, Boreham Wood, Herts., on the Elliott 402 computer. This was a mathematical model of a hydro-electric scheme operated by the British Aluminium Co. Ltd., viz., the Lochaber scheme in Scotland, which again concerns two interconnected reservoirs at different levels. The computer has facilitated the study of operating the system and has enabled the evaluation of overall gain in power which might be obtained if certain modifications were carried out. The programme, operated in time increments of one day, simulated the behaviour of the system over a period of 14 years in 45 minutes of computer time.

At Ferranti's London Computer Centre, 66/71 Newman Street, London, W.1, the Swedish State Power Board investigated an energy-balance problem —the balance between the electrical demand in the country and the use of hydro-electric power and steam power—on the Pegasus computer, water power being insufficient during the dry winter months but abundant in summer, thus giving ample production and enabling the reservoirs to be refilled. The programme consisted of more than 3,000 instructions which were run 360 times to cover the 30-year period investigated. When the computation was attempted by hand, it had to be simplified to a great extent and not all facets were considered, making the results unsatisfactory. Even so, it took an engineer some six tedious weeks to perform the calculation. The Pegasus computer, however, took half an hour to produce realistic results without any simplification of the problem and included the examination of a great number of alternatives.

There are many computer programmes available which can be of interest to the water-power engineer. The following is a list of DEUCE programmes which have been written or are about to be completed at the London Computing Service, Data Processing and Control Systems Division, English Electric Co. Ltd., Marconi House, Strand, London, W.C.2:—

Stresses and deflections in piping systems.
Calculation of sag and torsion of suspended cables.
Earth settlement calculations.

(Continued on page 319)

Fines in Concrete Mixes

Since we published an earlier article on this subject* detailed studies made in Austria have enabled a technique to be developed to grade the fines accurately and to obtain the optimum dust-removal limit for any desired concrete mix. This technique has been applied to the building of some of the most important hydro-electric structures in Austria and elsewhere in Europe†

By Dipl. Ing. Dr. JOSEF FRITSCH

IT has long been known that the finest sand fractions have an important effect on the properties of fresh and hardened concrete; little attention, however, has been paid in the past to the proportion and composition of the fines in the aggregate. The main reason appears to be that no suitable site equipment was available to control the quantity and composition of these finest constituents with any degree of accuracy, or even to remove completely all fines below a certain limiting size. The finest sieves used for large-scale grading on site had a mesh size of 3 mm., or in exceptional cases 2 mm. The finer constituents were then removed to a varying degree in washing plants without any possibility of recovering them or subdividing them into indivdual fractions.

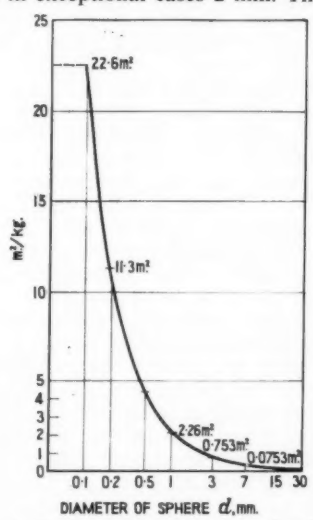

Fig. 1. Surface area of 1 kg. of spheres

It has always been known, however, that a dense concrete mix must be completely free from any voids between the larger particles. This leads to two conflicting requirements: on the one hand the interstices must be filled as thoroughly as possible by careful grading of the fines, while on the other hand it is impossible to achieve good workability and a homogeneous material even with the optimum aggregate grading unless the individual particles are completely surrounded by cement paste.

Cement-Paste Requirement and Surface Area of Aggregate

If we now consider the relationship between the size of the particles and their surface area we understand the decisive influence which the constitution of the extreme fines exercises on the cement requirement. It is appropriate here to refer to the well-known illustration of the surface area of one kilogram of sand consisting of spheres of different diameters. It is evident, for example, that a sand of 0·1 mm. diameter has a surface area thirty thousand times as large as sand of 3 mm. diameter (Fig. 1).

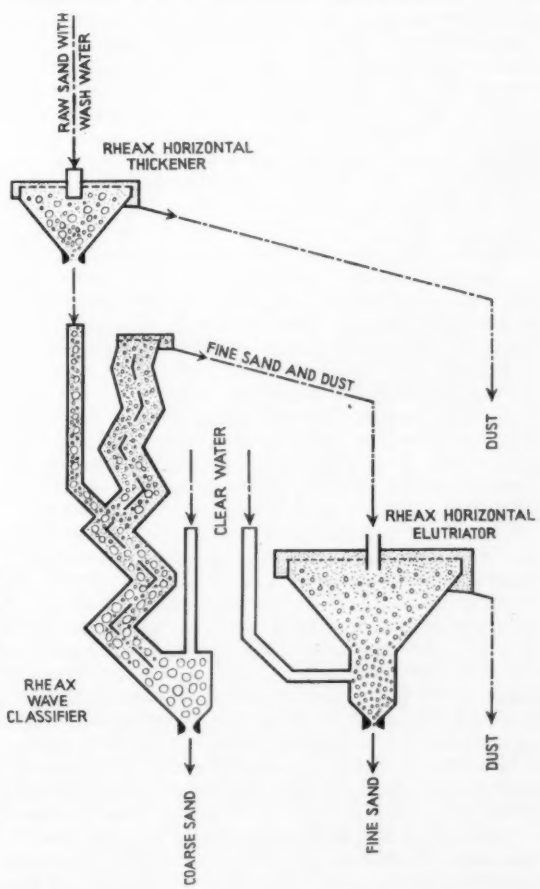

Fig. 2. Diagram of a combined Rheax washing plant

* "New Experience in Mass Concrete Construction," by Dipl. Ing. Dr. Josef Fritsch, WATER POWER, July and August 1954, pp. 259 and 304.

† The present article originally appeared in German in *beton Herstellung Verwendung*, No. 8, 1959, published by Beton-Verlag GmbH, Dusseldorf, Germany.

The spaces which may eventually remain between the smallest particles must be filled with cement paste in order to achieve a fresh concrete of maximum density. If the proportion of fines is too small, the number and size of the voids increase rapidly, while an excessive proportion of fines leads to a rapid increase in surface area. Both cases result in an appreciably increased requirement of cement paste.

Definition of Optimum Grading

In each case there is therefore a unique optimum grading of the extreme fines which results in completely dense concrete with a minimum amount of cement paste and compaction. This will be discussed here in relation to the basic principle on which its practical evaluation in each indivdual case depends. The considerations discussed below are based on information which is by no means new to concrete technology or even difficult to understand, but which has nevertheless not yet been applied in practice to a sufficient extent.

It was already stated by Abrams that the strength of a concrete under otherwise identical conditions depends only on its water-cement ratio and on its compaction. Today it can be assumed that virtually complete compaction of the fresh concrete is achieved on site, using easily workable mixes and modern vibration methods; the degree of compaction thus ceases to be a variable characteristic and the concrete strength depends essentially on the water-cement ratio. This fact is little affected by the results of recent research which involved highly accurate tests and indicated slight deviations from Abrams' law.

When designing a mix, the concrete engineer must therefore determine as a first step the water-cement ratio which is necessary to achieve with safety the strength required by the structure, using the material available on the particular site. This presumes that characteristics other than the strength, such as impermeability to water, resistance to frost, etc., can be neglected. This chosen water-cement ratio must then be maintained throughout the subsequent tests to establish the optimum grading. It is assumed that these tests cover only mixes having the required workability during placing, and that virtually complete compaction is in fact achieved.

If the strength, the grade of cement and the water-cement ratio have been chosen, the only remaining characteristic for judging an aggregate grading is the amount of cement paste required to achieve reliably the compactibility necessary for the site. While in theory this depends on the shape of the entire grading curve, the finer fractions are found in practice to represent the main influence. While mixes of different composition with the same water-cement ratio, after complete compaction, have approximately the same strength, this must not be allowed to obscure the frequently important technical and economic differences introduced by changes in the cement-paste requirement. Although the heat developed by a cement may sometimes lead to trouble, the cement remains a valuable constituent both as part of the grain structure and also as the carrier of the entire strength of the concrete. There is, however, no property of the hardened concrete which does not deteriorate with increase in the amount of water introduced into the concrete together with the cement even at a constant water-cement ratio. We are thus able to formulate the law which forms the basis of our investigation:—

"Under otherwise identical conditions, a grading represents an optimum in both technical and economic respects if the required workability is achieved with the minimum amount of cement paste of a given composition."

It seems advisable here to deal in greater detail with these relationships since experience has shown that the requirement of minimum cement paste in a mix frequently leads to misunderstandings in practice. The difficulty in the practical application of this by no means novel idea lies not so much in the necessary control of the fines and extreme fines but rather in counteracting the idea that increasing the amount of cement always produces an improvement in the concrete, and to convince the authorities responsible for contract specifications that a mix with the same water-cement ratio increases in value under otherwise identical conditions if it contains *less* cement paste. This involves at the same time a change in our attitude towards all specifications which in many cases continue to lay down a minimum cement content; in this way they frustrate all reasonable efforts aimed at a better utilisation of our resources in construction materials and result in excessively high strength under favourable conditions, thus indicating how far they are removed from the true conditions. An example will show how easy it is to run into difficulties with the old specifications regulating cement content and workability. On a large site (where incidentally the contract specified that the grading curve must if possible lie in the "specially good region") the addition of the required water was left to be decided on site, i.e., by the experienced mixer operator, while the water-cement ratio was usually determined only in the laboratory, if at all. It was also proved in the laboratory that it was quite possible under these conditions to produce concrete cubes which achieved the specified strength. In actual fact it happened sometime that the sand supplied to the site had a higher proportion of extreme fines than had been assumed in the preliminary tests. The experienced mixer operator knew what to do; he simply increased the amount of water added until he achieved again the same workability. The curve above (Fig. 1) shows that the increase in the proportion of fines resulted in a very rapid increase in the total surface area of the aggregate and with it in the water requirement, while nobody noticed these variations during the placing of the concrete. Because of this increased water content the workability of the concrete remained approximately the same as before. In actual fact the addition of further water while maintaining the proportion of cement greatly increased the water-cement ratio and caused the strength to fall in the same proportion. The most unfortunate point, however, was that the contract specification was met completely in this case since it covered only cement content, workability and grading curve.

In order to resolve this apparently contradictory requirement of a minimum amount of cement paste, we have to appreciate how the idea of the "strength-producing value" of an aggregate on the one hand and of a fixed proportion of cement on the other may have arisen and eventually became embodied into the old concrete technology as an incontrovertible fact. Previously the proportion of cement was based on the cement content of one cubic metre of compacted concrete. This value was used in all publications and formed the basis of standards and tender

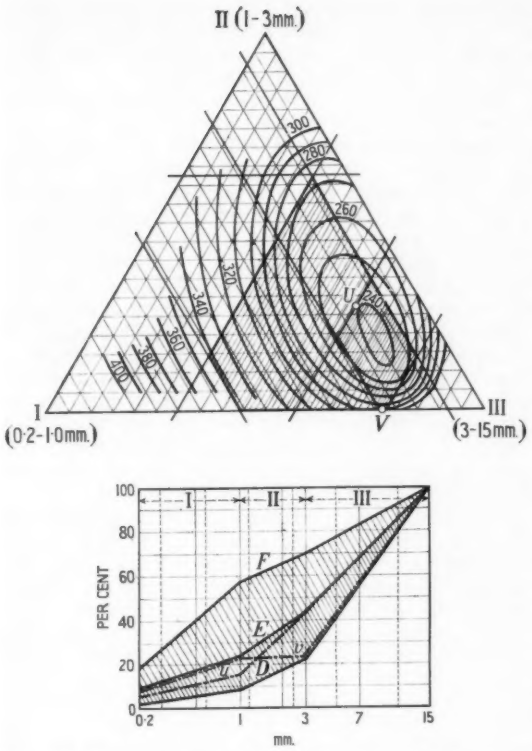

Fig. 3. Aggregate consisting of three particle groups. Comparison of diagrams

specifications. The direct connection between cement content and concrete strength was regarded as an undisputable fact and as sufficient evidence to characterise the concrete, and was eventually also used to evaluate sands and gravels. During the standardised compaction test, sufficient water was then added to each mix to achieve complete compaction as well as the strength corresponding to the cement content. In this way the water-cement ratio and the strength were defined as a function of the type and composition of the aggregate, leading to the above-mentioned idea of a "strength-producing value," which contrasts with today's concept of a requirement of cement paste having a given composition.

Separating the Fines

The outstanding influence of the extreme fines on the total surface area of the aggregate and with it on the amount of cement paste required to surround the particles completely indicates the direction to be followed in order to achieve further progress and success. It is only in exceptional cases that the sands available on site include limited grades in the finest range. It is generally necessary to separate the finest fractions on the actual site itself, but the type of plant used in the past did not allow a successful separation of the finest constituents.

That we have now managed to progress beyond this dead point is due to a considerable extent to fresh developments which were demonstrated on sites abroad. It was recognised in America that the additional cement which previously was necessary on the grounds of safety could largely be saved if variations were prevented at the point where they arose. This has led to the design of the American type of separating plant which in its original form was intended mainly to maintain constant conditions and to reduce the variation in fineness modulus to a minimum which had previously been unobtainable. Horizontal washers with four, six or eight chambers, the so-called "hydrosizer," further subdivided the fraction passing through the last sieve (usually 0 to 4·8 mm.); sieve analyses were carried out continuously to decide which of the various fractions obtained from the four, six or eight outlets of the hydrosizer should be added to the mix and which discarded. In this way it is possible to exert a large measure of control over the composition of the finest constituents. This method divides the sand not in sharply defined grades but into fractions which overlap considerably, and practical experience has shown that it does not permit completely accurate control; this is due partly to the time required for a sieve analysis (1–2 hours), and partly also to psychological factors. These American methods nevertheless represent a definite and important step forward in view of the improved utilisation of the material and in particular the very uniform quality of the concrete produced. The most valuable outcome, however, was the suggestion to proceed one step further in this direction and to seek a solution which virtually represents the complete separation of the finest fractions. With the Dorr separation plant described above it is possible to influence the fineness modulus to a considerable extent, but the use of individual fractions such as we are doing today even in the finest range is no more possible by this method than any attempt to specify and maintain a certain tested composition of the finest fractions.

It was in any case certain from the start that the most important step in our "fines technology" must be a more or less complete removal of the finest dust-like particles which are found especially in material which is obtained dry, either from mountain moraines or from valley deposits. We usually find in them remains of rock materials which are useless for concrete — weak, weathered and very soft rock which could offer little resistance to the natural diminution process. With the customary method of washing the aggregate in separating and washing plant of various types, it was unavoidable that an appreciable part of the fine, round and sound grains which are most important for concrete structures, were washed away together with soil and dirt. It is evident that a separating plant can only prove satisfactory for this application if it operates according to the usefulness of the sand for the manufacture of concrete; all particles of rod, splintered, laminar or otherwise unsuitable shape have to be removed, as well as those constituents which are less suitable because of their low strength, while all sound, spherical fines must be retained.

It thus became necessary to develop new methods and equipment by means of which it would be possible, both on a small scale in the concrete laboratory and also at full scale on site, to remove completely the unsatisfactory fines up to a definite size limit which has to be decided on in each case, and in addition to separate the fines into fractions contained between definite limits which can then be added to the mix in the same way as previously the coarser fractions. Progress has been achieved by using a method which was originally developed for kaolin

production and which was later introduced to concrete technology. This equipment is known under the name "Rheax" and utilises the differences in the sedimentation velocities of different particle sizes in water. In this vertical washing plant, which has been described several times in technical literature, the particles descend against an upward stream of water. By this arrangement any particles of which the sedimentation velocity is smaller than the water velocity are prevented from reaching the discharge opening at the bottom of the separator from which the coarser fraction is drawn off.

This type of plant was tested and found reliable on many large-scale projects but offered scope for further improvement in certain respects. The sharpness of the separation, which did not reach the theoretical value owing to unavoidable vortex formation, could be improved considerably by lengthening the separating column. Such increases in length are limited, however, by the resulting loss of head in the plant. A further disadvantage of the existing installations was the very large amount of water required, which could not be reduced by any simple measures without affecting the quality of the separation; with low water flows it is impossible to prevent contact between the particles which immediately reduces the separating efficiency.

Attempts were then made to utilise the advantages of multistage separation with a closed opposed-flow system in a vertical washing plant. Since incorrect grading of one stage can readily be corrected in the subsequent stages, it is possible by relatively simple arrangements to achieve fairly high separating efficiencies which are readily comparable with those of industrial sieving plant.

These improvements are incorporated in the recently developed "Rheax" Wave Classifier which is shown diagrammatically in Fig. 2. The multistage effect is achieved by a succession of short vertical washing stages which are set at a slight angle. The addition of guide plates permits the use of a smaller dilution since the various constituents remain suspended separately The raw material is introduced at the centre in the form of a fairly concentrated suspension so that the correction of the sizing error applies to both output fractions The coarse fraction is withdrawn through an adjustable opening at the bottom of the classifier while the fine fraction leaves at the top together with the wash water. The separation particle size is controlled by the flow velocity which depends on the size of the openings and on the pressure at the water inflow and outflow.

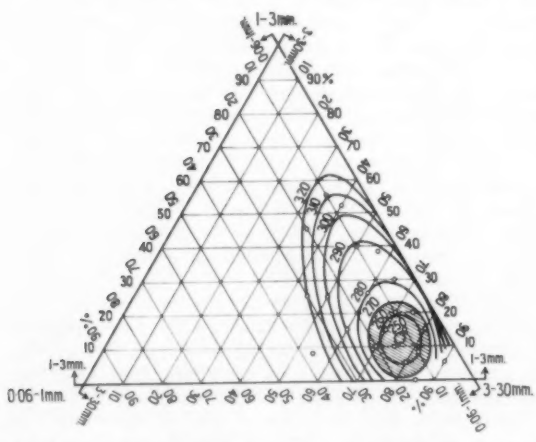

Fig. 4. Curves of equal cement requirement. W/C = 0·5

The diagram shows a Wave Classifier operating in conjunction with a dust removal plant. The raw sand, which generally falls within the range 0–3 mm. usually arrives from the separation plant with a fairly high water content and is passed first to a horizontal thickener the overflow from which separates the excess water together with part of the dust fraction. The Wave Classifier now separates the coarse sand which passes down, from the remaining dust and the fine sand which are passed to a horizontal elutriator where further water can be added. The amount of water required for a complete single-stage plant is approximately 3–3½ litre per kilogram of raw material, only about half of which has to be fresh clean water. To remove the coarse sand from the bottom outlet a further 0·6–0·7 litre per kilogram is required; this water is practically unaffected and can be recovered from the dewatering plant without clarifying.

The sand fractions discharged from the grading and dust-removal plants are dewatered in the Rheax vibro-dewaterer plant which has recently been developed. This equipment does not use sieves; instead, part of the wet sand acts as the filter layer through which the water passes to the discharge openings under the effect of vibration. The output of this vibro-dewaterer plant is practically free from water drainage so that the lower layers in the storage silo are no longer wetted. It is impossible to overemphasise the advantage of using sand of such uniform moisture content in the manufacture of concrete.

Advantages and Achievements

We shall now deal with the advantages which this type of grading plant can bring on a well-organised site. It is important to recognise, however, that local conditions and variations in material have a very much greater influence on the fines discussed here than on the coarser grades. Natural deposits requiring no further grading or cleaning occur only very rarely in the neighbourhood of our large construction sites. In most cases it has been found advantageous to remove all the extreme fines up to a certain size, since the dust nearly always contains the low-grade components which are better replaced by sound and carefully graded fine sands, supplemented if necessary by artificial air cells. It has been proved in practice that carefully designed dust removal from the raw aggregate is of considerable advantage on nearly every site, resulting in a concrete with improved resistance to weathering and less pervious to water while at the same time requiring less water and cement.

Combining the dust removal with a sharp division of the sand below 3 mm. into two fractions brings further advantages:

1. As already mentioned, the constitution of the finest particle sizes has a decisive effect on the value of the entire mix. Its composition has a greater influence on the suitability of the mix than the constitution of the coarser aggregate. Control of the finest size thus enables us on practically every site to achieve an improvement in workability while at the same time reducing the amount of cement paste required.

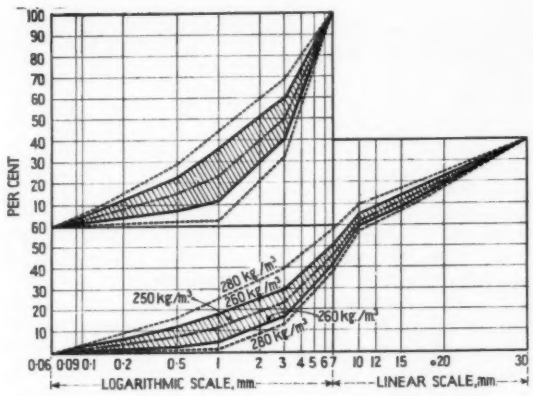

Fig. 5. Grading curves corresponding to areas of equal cement requirement in Fig. 4

2. Accurate proportioning of the fine sands removes the main cause of the variations in concrete quality which had previously been considered to be unavoidable; it provides the basis for a uniformity which was impossible to achieve with the plant used previously. It follows that it is no longer necessary to use a larger amount of cement as a "safety" measure, which generally only causes a reduction in concrete quality.

3. We know that variations in the quality of the hardened concrete in a structure are usually attributable to poor compaction of the fresh concrete. Controlling the finest grades allows uniform workability to be maintained and thus ensures virtually complete compaction of the fresh concrete at all times.

4. This provides the basis for dispensing with the cement content as a fundamental characteristic of a mix, and permits the use of the relationship between water and cement, the W/C ratio, under practical conditions.

5. It is known that the effect of the various air-entraining agents, i.e., the number of air cells produced for a given amount of material used, depends largely on the composition of the extreme fines. The removal of dust from the aggregate as described above not only produces uniformity in this range but also forms the basic condition for continuously producing a definite air content.

On the first large sites where this control of the fines was employed, at the Upper Kaprun stage of the Tauernkraftwerke A.G., and at the Danube power stations at Jochenstein and Ybbs-Persenbeug, we have in fact achieved not only an improvement in concrete quality but also a saving in cement amounting to 15–30%. Of greater importance than these savings, however, was the improvement in the concrete due to removing the main cause of quality variations.

Research and Development

Introduction of the grading of finest sand on our construction sites brings with it the obligation to investigate the relationships which were previously beyond accurate control. Although millions of cubic metres of concrete have already been produced in Austria and in other European countries by utilising this method, there has so far been no systematic investigation into optimum values for separating the sand and reconstituting the aggregate which are essential for achieving the best results. We are here faced with a task the importance and difficulty of which is frequently underestimated. It is by no means the case that the grading curve previously used for the coarser constituents can simply be extended to the smallest sizes. Certain factors are introduced in this range which make a separate determination necessary of the optimum constitution of the fines in each individual case. The shape and quality of the finest particles the composition of the sand in the range of its finest constituents, even the cement particles themselves and any additives used, as well as the required workability of the complete mix, all play their parts, which vary from site to site and can no longer be neglected.

Such investigations become simplified if we abandon the assumption that the grading influences the strength, and consider instead the dependence of the concrete properties on the W/C ratio, starting from the strength required by the designer for the particular structure. The first step is to determine by a simple preliminary experiment the W/C ratio corresponding to this strength. Next we have to establish the amount of cement paste required and retain it as the characteristic required for each mixture of the various aggregates to achieve the specified workability. This involves mainly a reliable evaluation of the workability of the fresh concrete mix as required on the site; it can be determined, for example, by means of the vibration tester which has been described on several occasions. Using this instrument it is possible to determine the amount of cement paste required for each test with an accuracy of 2 to 3 kg. of cement per cu. m. of concrete. For soft mixes which are not vibrated but tamped, the value is determined by graphically recording the transformation of the concrete in a Powers instrument. The slope of the settling curves obtained with this instrument represents a useful measure for the workability of the concrete as it becomes evident during compaction.

Our task is now to determine the relative proportions in which the finer fractions have to be added in order to achieve the required workability with a minimum amount of cement paste. In the past it has been usual to choose a suitable particle grading based on a standard specification or some other empirical data, and then to prove only that the specified requirements can be met with it. It is undeniable that good, and often even very good, mixes were developed and tested in this way. There was no assurance, however, that these preliminary tests covered the optimum mix obtainable under the particular conditions. The method to be described below takes account of this fact and provides a simple graphical presentation from which the optimum value obtainable with the most favourable grading curve can be determined. A number of mixes, the grading curves of which are arranged to differ considerably, are tested as mentioned above, determining the amount of cement paste required to achieve reliably the workability which was originally specified. A convenient presentation is provided by the three-component diagram used by Feret in 1896 for a similar application. If the proportions of the three finest fractions are plotted in such a diagram and points of equal cement requirement are joined together, we obtain curves the centre of which corresponds to the minimum amount of cement paste required and at the same time to the most thorough compaction of the particles. Fig. 3 shows how the so-called "satisfactory" and "excellent" ranges referred to in Austrian specifica-

TABLE I

Fraction	Percentage passing mesh size						
mm.		0·042	0·06	0·09	0·2	0·5	1·0 mm.
I, 0 to 1·0 (dust not removed)		22	38	48	64	80	100%
I, dust removed at 0·042 ...		1	9	13	39	68	100%
I, dust removed at 0·06 ...		—	1	10	34	64	100%
I, dust removed at 0·09 ...		—	—	—	14	46	100%
	1	2	3	7	10	15	30 mm.
II, 1·0 to 3·0 mm.	2	73	99%	—	—	—	—
III, 3·0 to 30 mm.	—	—	1	30	51	62	98%

tions can be plotted on such a three-component diagram. It is evident that this provides much more accurate information on the value of an aggregate than the usual type of grading curve. In particular it is possible to read off directly the difference between the actual amount of cement required by a mix and its optimum value. The two grading curves U and V shown in Fig. 3 as examples are seen in the three-component diagram to exhibit a very appreciable difference in cement paste requirement although both pass through the "excellent" region of the standard grading curves.

Recent Test Results

While it is impossible for these reasons to establish rules for building up a mix from its finest fractions in a form which has general validity, the Engineering Test and Research Station of the Österreichische Elektrizitätswirtschafts-A.G. in Kaprun has started experiments with a view to determining the optimum constitution of the finest fractions in a form having the widest possible application based on the experience gained on our construction sites during recent years. Although the results are by no

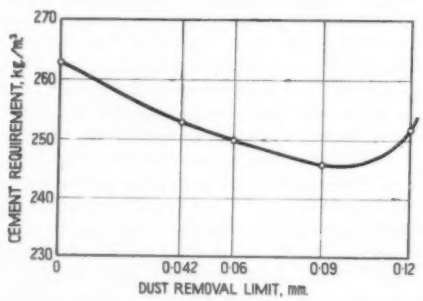

Fig. 6. Cement requirement as a function of dust-removal limit

means directly applicable to other conditions, they may at least serve as a general guide on many other sites.

In order to obtain a series of optimum values for different aggregates, three fractions were used to make up the aggregate and only the proportion of the individual groups was varied during the tests. The limitation to three fractions has proved a useful and reliable procedure for the purpose of this development work. Since the effect of particle size on cement-paste requirement increases as the particle size is reduced, the following fractions were used throughout all the tests:

Fraction I: finest sizes up to 1·0 mm.
Fraction II: from 1·0 to 3·0 mm.
Fraction III: from 3·0 to 30 mm.

The composition of the sands within these fractions is given in Table I.

In order to obtain the results in a most generally applicable form, Danube aggregate was used throughout as its particle shape and mineralogical constitution can certainly be taken to represent average values. The sands consisted of quartz and carbonate, of essentially compact and usually rounded shape, and were always sound and free from low-grade constituents. The cement used was PZ 275. The value determined

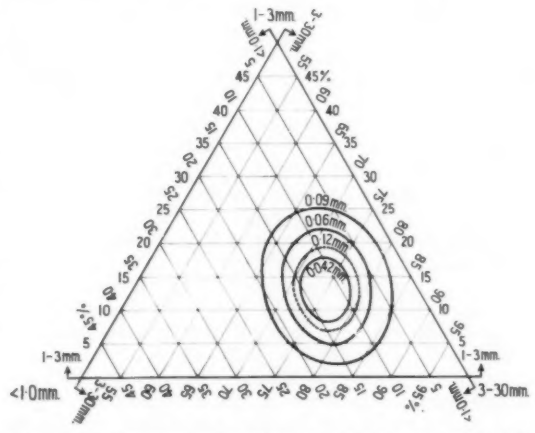

Fig. 7. Areas corresponding to aggregates with 260 kg. per cu. m. cement requirement at different dust-removal limits

for each test was the amount of cement paste required to obtain an accurately defined compaction curve on the vibration tester. This represented a mix as used for example for road surfaces.

Example I. Throughout the tests of the first series a W/C ratio of 0·5 was used and the dust-removal

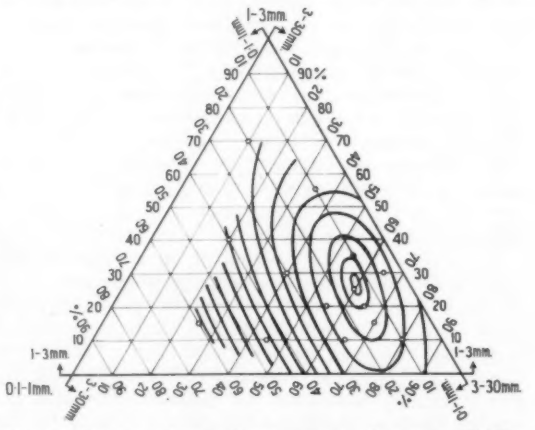

Fig. 8. Curves of equal cement requirement. W/C = 0·63

limit set at 0·06 mm. Various aggregates were then produced from Danube river material, the amount of cement required being determined for each and points of equal cement requirement connected by curves (Fig. 4). These show clearly the regular nature of the test results and give as their centre the required region for the composition of the optimum mix which is defined by the minimum cement paste requirement (250 kg. per cu. m. of concrete) and the maximum weight. The three fractions are present in the following proportions:

0·06–1·0 : 12%
1·0 –3·0 : 12%
3·0 –30 : 76%

The improvement and the success of this type of diagram lies in the possibility to read off directly the increase in cement paste required if the size fractions are used not in their optimum relationship but in different proportions due to unavoidable variations in the sand supply or for economic or other reasons. The use of the proportions mentioned above on an actual site will in fact represent only in exceptional cases the most economical solution. In general one or the other of the fractions will be much more expensive, and the most economical mix is represented by a point in the three-component diagram which takes account of this fact and which reduces the proportion of the most expensive fraction through a slight increase in cement content.

From the constitution of the individual fractions as shown in the table it is possible to transform the triangular representation of the individual values into the graph generally employed for grading curves (Fig. 5). The shaded area in Fig. 5 represents the area in the three-component diagram within the curve corresponding to a cement requirement of 260 kg. per cu. m.; the middle, dashed grading curve represents the optimum value shown in Fig. 4 which corresponds to 250 kg. of cement.

If, for example, the grading curve used does not correspond to the optimum curve but to one of the boundary curves shown as full lines in Fig. 5, the same workability would require, under otherwise identical conditions, an extra 10 kg. of cement per cu. m. of concrete. Fig. 5 also shows the boundary curves corresponding to 280 kg. of cement. When interpolating it is important to note that intermediate grading curves must have a slope which is reasonably the same as those of the boundary curves.

As mentioned at the beginning, this diagram has been developed for particular conditions and cannot be applied directly to cases where these requirements no longer apply. Experience has shown, however, that relatively small variations in important characteristics such as dust-removal limit, W/C ratio, etc., may alter the amount of cement paste required and the quality of the hardened concrete but affect the position of the optimum point in the diagram and the shape of the optimum grading curve only to a much smaller extent.

Example II. The tests described above were carried out with an aggregate in which the extreme fines had been removed completely below a dust-removal limit of 0·06 mm. As a result we obtained an optimum aggregate composition corresponding to 250 kg. cement per cu. m. If the complete range of tests is repeated using an aggregate with a higher or lower dust-removal limit, there is an appreciable difference in the amount of cement paste required. The values

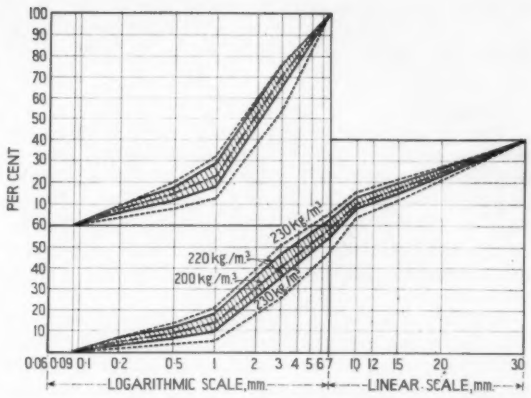

Fig. 9. Grading curves corresponding to the areas of constant cement requirement in Fig. 8

obtained for the various cases are shown in Fig. 6. It is evident that in this series of tests the optimum value is reached with a dust-removal limit roughly between 0·09 and 0·1 mm. As is to be expected, the cement requirement increases with the proportion of extreme fines and thus with the total aggregate surface area which has to be covered by the cement paste; but the cement-paste requirement also increases if the proportion of fines becomes too low.

These results do not necessarily apply to all cases. In fact the optimum dust-removal limit depends greatly on the water-cement ratio, and also on the amount and particle size of the cement used, on the presence and proportion of air-entrainment agents, and on the composition of the extreme fines; these factors have a greater effect on the dust-removal limit than on the shape of the optimum grading line mentioned above.

The effect of the dust-removal limit on the cement-paste requirement can also be expressed in a different manner. We have evaluated the results of the various series of tests for different dust-removal limits in the same way as shown in Fig. 4 for a limit of 0·06 mm.; we have then determined on each diagram the area corresponding to a cement requirement of 260 kg. per cu. m. These ranges are shown in Fig. 7 to a somewhat larger scale. The diagram shows quite generally the very important effect of the dust-removal limit on the mix and on the amount of cement required. For a case corresponding to the conditions in the tests mentioned above, this diagram can be utilised as follows: if the proportion of cement for a particular structure has been specified as 260 kg. per cu. m. for example, then the curves show the regions within which the three aggregate fractions may be mixed with the appropriate dust-removal limit without exceeding the stated cement requirement.

Example III: While the examples I and II referred to high-grade concrete, similar tests were carried out independently at another laboratory with a W/C ratio of 0·63 and a dust-removal limit of 0·09; the results are shown in Figs. 8 and 9. Neither the position of the optimum point in the three-component diagram nor the actual grading curves agree with those determined from the tests, as was to be expected. The higher proportion of water in the cement paste results in a much narrower range of grading curves. Furthermore, the optimum aggregate com-

position involves a greater proportion of the finest fractions, a requirement which affects the entire range from 0 to 3 mm.

Conclusions

The examples described cannot claim to represent the entire picture since we are only at the start of this development. They have, however, provided the proof that there is no generally applicable optimum value for the composition of the extreme fines. In this region it is necessary to determine the optimum size distribution in each individual case by means of fresh tests.

Experience so far shows that it is possible on each site to develop an optimum composition of the finest constituents and in this way to achieve a better utilisation of the aggregate and a better concrete quality.

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Asian Soil Mechanics Conference

A brief review is given of the First Asian Regional Conference of the International Society of Soil Mechanics and Foundation Engineering, held at New Delhi recently

IN accordance with the statutes of the International Conference of Soil Mechanics and Foundation Engineering providing that a regional conference be held during the period intervening between two International Conferences, the First Asian Regional Conference was inaugurated in New Delhi (India) by Shri Jagjiwan Ram, Union Minister for Railways, on February 4, 1960.

Dr. K. L. Rao, Vice-President of the International Society of Soil Mechanics and Foundation Engineering for the Asian Region, presided. Shri Jai Sukhlal Hathi, Union Deputy Minister for Irrigation and Power, Dr. A. N. Khosla, Member of the Planning Commission and Founder President of the Indian National Society of Soil Mechanics and Foundation Engineering, and Monsieur Armond Mayer, Vice-President of the International Society for the European Region, attended the session, along with many engineers and scientists from different parts of India and other countries, namely Israel, Japan and U.S.S.R. Shri Baleshwar Nath, Secretary, Central Board of Irrigation and Power, was the organising secretary of the Conference.

Dr. K. L. Rao, in his presidential address, presented a brief review of the early contributions made in the science since 1773. He pointed out that the main defect in earlier thinking on the subject lay in completely neglecting the properties of soils. Dr. Karl Terzaghi had since contributed greatly toward evolution of soil sciences and was the founder of the present science of soil mechanics. He stressed that further development of the science required collection of field data so that the effects of the heterogeneous nature of soils, undisturbed soil structure, lapse of time, etc., might be studied in greater detail.

Dr. Rao further stated that the science was being employed extensively and great economies had been achieved in some of the most important works in India such as the Hirakud dam, which is perhaps the longest earth dam in the world, being nearly 15 miles. Kotah dam, 120 ft. high, built on a highly permeable substratum, approach embankments at Mokameh bridge, express highway near Bombay on marshy ground, cement-concrete flexible pavement for roads in a new township near Bhopal, construction of Kandla Port on a soft and slushy area and extension work at other ports. He also laid stress on the need for the early establishment of private consultation laboratories with site investigation equipment.

Two subjects were selected for discussion at the Regional Conference. They were "Construction and Behaviour of Earthen Embankments," and "Foundations of Structures other than Hydraulic Structures."

Fifteen papers presented on the first subject, covered the construction techniques of earthen embankments, field behaviour, defects and remedial

measures, seepage observations, failure, and causes thereof. The twelve papers presented on the second subject covered site investigations and design of foundations, causes and effects of settlement, and treatment of special soils. Apart from the papers selected for discussion, ten papers were also presented as communications on soil properties and their measurement, including general soil stabilisation techniques and technique of field measurement and sampling.

The first subject, "Construction and Behaviour of Earthen Embankments," was presented for discussion by the General Reporter, Dr. R. C. Hoon, Director, C.W. and P.C. (India). Salient points as emerged out of the papers were:

(i) By providing a standing filter behind the impervious zone connected to the downstream by a horizontal drain at the base of the dam, the downstream slope would be dry and would reduce pore pressure even for the worst case of rapid drawdown.

(ii) In remodelling of old earth dams, the attention of soil engineers has been drawn to two principles, viz., the age of the old dam and the conciliation of differences in the engineering properties of soil used in the old dam and that intended to be used in its remodelling.

(iii) From laboratory study, it is shown that for cohesionless material such as sand, instead of merely combining the optimum static load and vibration, if the static load is applied in increments and sand vibrated after each increment, the density increases considerably and also it is observed that 100% saturation will yield densities as good as those under dry conditions if compaction by vibration is adopted.

(iv) It is also shown that using the relationship formulated by Rao (India) it will be possible to determine the compaction ratio in the same way as done by Hilf (U.S.A.), and the method offers further simplification of the experimental work involved in assessing soil-compaction ratio.

(v) Although the unconfined compression test has been considered useful for estimating the stability of an embankment, factors such as time lag between the occurrence of the slides and collecting of test samples, taking of the mean values of the test results, etc., seem to affect the results.

(vi) Analysis of excessive seepage in clay reservoir estimation of permeability has indicated greater effects of entrapped air in laboratory studies and thereby points out the importance of a study of physico-chemical properties of the soil, which is seldom taken into account in soil engineering.

The general report on the second subject, "Foundations of Structures other than Hydraulic Structures," was presented by Mr. Kano Hoshino, Institute of Industrial Science, University of Tokyo (Japan). The General Report brought out the following salient points:—

(1) A correlation between the swelling pressures in expansive clays and other soil properties has been presented along with the effect of width of foundation footing on swelling pressures.

(2) Handling of a weak compressible soil in the foundation by use of vertical sand drains which would effect quick settlement.

(3) Treatment of weak soils to improve their strength and other physical properties with some specific methods, such as silicate treatment of the soil by electroasmotic process.

The delegation from the U.S.S.R. presented three papers, which generally covered some of the achievements made in the field of soil mechanics in that country, especially on the relation between pore pressure and rate of creep, properties of compressible soils and their behaviour under loads, theory of foundation of finite thickness, design of foundation beds when the foundation bed devolves simultaneously plastic and elastic regions and stabilisation of soils carbamide resin.

Some useful points were raised during the lively discussions that followed. It was pointed out that in earth dams, where due to mechanised rolling the compaction would be thorough and failure of the downstream slope due to sloughing would follow eventually as a result of continuous downpour, it would be hazardous not to provide an impervious blanket.

There was a good deal of discussion on the practice of adopting either over or below optimum moisture content for proper compaction effort. There were two schools of thought, one advocating a higher value and the other a lower value. It was expressed that since the construction pore pressures depended on zoning and finally on flow nets, it would be of much advantage to place expansive clays at more than the optimum moisture content, which incidentally brings down swelling pressures. However, it was pointed out by one speaker that higher compacting effort would increase the dry density, thereby decreasing the optimum moisture content, which therefore was a function of the flocculated or dispersed condition of the clay and therefore the fixation of the particular value of the optimum moisture content depended on the nature of structure requiring different compaction effort, whether it was for a road surface, earth dam or some other structure. Regarding the use of an upstream membrane, limitations were pointed out that there should be availability of material for the membrane as well as the matching filter and at the same time careful analysis was needed as to the possibility of piping if at a later stage the dam was proposed to be raised. It was also impressed that in estimating seepage losses from laboratory experiments, care should be exercised to compare and preferably to arrive at the losses from field tests only.

An interesting talk was delivered by Monsieur Armond Mayer, Vice-President for the European Region, on the grouting operations adopted on the Serre-Ponçon dam and the Rhine valley scheme foundation treatment. Explaining the operations, he brought out the importance of the selection of grout mix after field permeability tests in the grout holes at different depths. He added that the cement grout would not be effective, since it could be used only in horizontal layers whereby watertightness would not be ensured. Also he cautioned against the existence of contact zones between alluvial and rock formations.

He also showed a film on the stabilisation technique adopted in one of the recent tunnel excavations in France in very loose soil, the stabilisation being effected by chemical injection first and followed up with cement grout to form a stabilised bulb.

Fig. 9. The machine hall of Tanzmühle power station

The Jansen Pumped-Storage Scheme

Economical and interesting civil-engineering designs and procedure have proved highly successful in this scheme on the River Pfreimd in East Bavaria

By Dipl.Ing. GERT NABER, Regensburg

PART TWO

The Pressure Tunnels

The Reisach tunnel connects the Reisach station on the Trausnitz Lake with the Rabenleite high-level storage reservoir. It runs at first for about 4,000 ft. (1,200 m.) at a slight falling gradient and under maximum cover below a ridge, and then continues as a vertical shaft some 500 ft. (150 m.) deep. Its diameter is 16 ft. 4 in. (4·90 m.); the maximum operating head (including waterhammer allowance) is 780 ft. (23 atm.) and the maximum static head 605 ft. (17·8 atm.). The tunnel has a steel lining until the rock cover reaches 200 ft. (60 m.), and its lower end is divided to form a manifold. This latter has been designed for the maximum internal pressure with a safety factor of 1·6 based on the failure strain, and has then been concreted into position. "Colcrete" was used to keep shrinkage to a minimum; during the setting of the concrete the manifold was kept filled with water under 340 ft. (10 atm.) head. The steel lining originally extended 230 ft. (70 m.) into the rock, but was extended following the first filling test (see page 314). The following method was chosen in order to reduce the diameter as little as possible and thus keep the flow losses low.

A concrete section of the tunnel, about 30 ft. long, was opened up into an expansion chamber to serve as assembly area. Three plate sections were welded together into a lining ring of 15 ft. 10 in. (4·75 m.) internal diameter; this procedure had to be adopted because the existing adits were not large enough for these heavy steel units. The assembled ring was then moved to its final position, a maximum distance of 100 ft. (30 m.), and the circumferential joints welded together. Although the spacing between ring and concrete lining was only 2 in. (5 cm.), the installation was completed without difficulty. Special attention was paid to maintaining a maximum permissible out-of-roundness of 0·5%. The space between pipe and concrete was grouted from the inside of the pipe after arranging suitable supports; this was followed by a final grouting of the rock.

Both steel-lining sections were designed for maximum internal pressure with a safety factor of 1·1, based on the failure strain. Although the geological survey had indicated that the Reisach tunnel would pass through firm sound granite, it was obvious that special measures would have to be taken when using a simple concrete lining at the internal pressure specified. This solution was chosen because of a shortage

of heavy steel plate at the time and also from hydraulic considerations. An attempt was made to protect the particularly weak invert and roof sections by inserting a hydraulic pressure cushion which was to provide prestressing of the concrete lining. These cushions were formed from thin, highly expandable steel sheet; it soon became evident, however, that the prestressing effect was limited to a relatively small area and in particular did not extend to the sides of the tunnel. In addition, the expected rock pressure only materialised to a small extent. The rock formation was in fact very variable in character, consisting mainly of large blocks of gneiss granite with clay-filled fissures of variable size. It thus proved impossible to drive the tunnel by the full-face method; a bottom heading was driven first, and the roof and sides were then excavated.

The relatively poor rock formation encountered resulted in an overbreak of 13·5%. The length of a round varied between 4 and 6 ft. (1·2–1·8 m.); either a single or a double wedge arrangement was employed depending on the strength of the formation, and millisecond firing was used in order not to disturb the existing stress distribution in the rocks more than necessary, due to the waves from the individual shots. Sections passing through poor rock were protected either by an arch or by torcreting. The shaft was excavated under difficult conditions, especially in regard to ventilation, from the bottom upwards by means of a blind shaft. The original intention had been to drill a bore hole 12–16 in. (300–400 mm.) diameter down from the floor of the high-level reservoir which would have been very useful for ventilation and upward excavation; the drill unfortunately became stuck at a depth of 230 ft. (70 m.) and the attempt had to be abandoned.

The concrete lining of tunnel and shaft has a minimum thickness of 14 in. (35 cm.) and was completed in sections or lifts of 30 ft. (9 m.). For constructional reasons the invert had to be completed later, an arrangement which had certain disadvantages connected with the load distribution. The gap between concrete and rock was grouted with very great

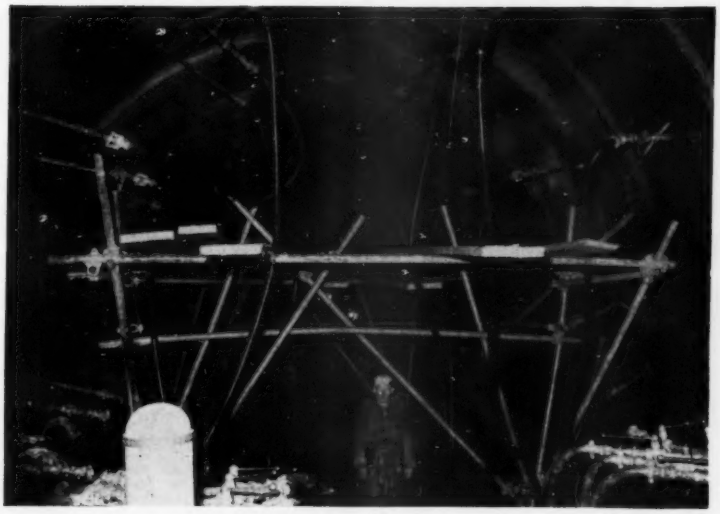
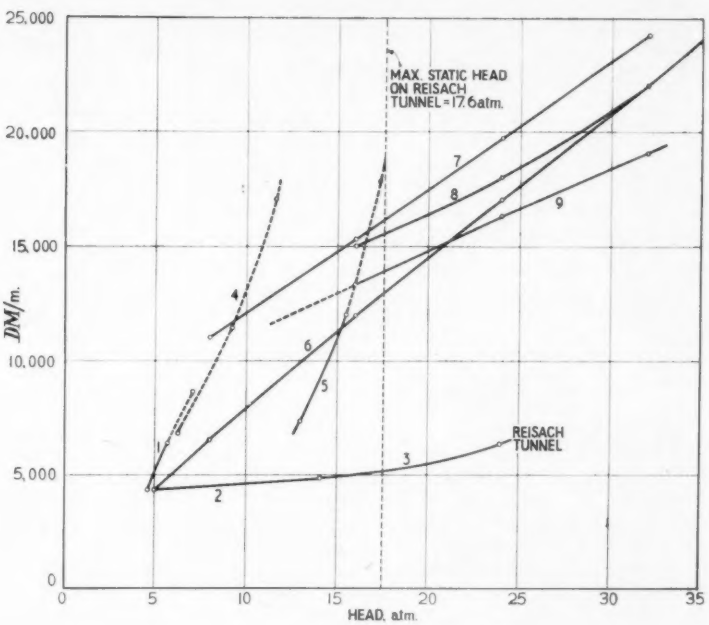


Fig. 10. Grouting injection for prestressing concrete lining



1. Simple concrete lining without effective rock support (concrete thickness 0·4-1·2 m.).
2. Simple concrete lining with rock support (concrete thickness 0·4 m.) increased grouting.
3. As 2 but with prestressed grouting.
4. Reinforced concrete without effective rock support (concrete thickness 0·4-1·2 m.), reinforcement 6%, factor of safety 3.
5. Reinforced concrete with rock support (concrete thickness and reinforcement as in 4).
6. Unsupported steel pipe, factor of safety 2·5, based on elastic limit.
7. Pipe tunnel (concrete 0·4 m. thick, 6·40 m. internal diameter), steel pipe with factor of safety of 2 based on elastic limit.
8. Individually prestressed reinforced concrete pipes.
9. Lined tunnel, factor of safety of 1·5 based on elastic limit assuming ¼ of load taken by rock.

Fig. 11. Attempted representation of cost comparison for different Reisach tunnel arrangements based on 1956 prices, 4·90 m. internal diameter

care, using 1·6 in. (40 mm.) diameter drill holes 5 ft. (1·50 m.) long and a pressure of 75–90 lb. per sq. in. (5–6 atm.). After pressurising the hydraulic cushion at roof and invert as already mentioned, individual grouting was carried out at 600 lb. per sq. in. (40 atm.), especially at the sides. The amount of cement used was 4·4 lb. per sq. ft. (22 kg. per sq. m.) of tunnel surface. The first trial filling with cold water in the early winter of 1954 had to be interrupted because of high water leakage at 475 ft. head. It was then decided to extend the steel lining. A promising method was developed in co-operation with the contractors to carry out the prestressing groutings over the whole concrete tunnel and shaft. The rock was prepared to absorb further injections by systematically washing out all the clay from the fissures. The boreholes were drilled obliquely, depending on the direction of the main fissures, in order to cut as many of the strata as possible. A surface-tension reducing agent was added to the water in the proportion of 0·2–0·4%; this helped in dissolving the clay and kept it in suspension until it was washed out. This was followed by simultaneous grouting over the entire zone, where possible, using a pressure of 600 lb. per sq. in. (40 atm.) and up to 20 grouting holes (Fig. 10). Finely ground blast-furnace grouting cement was used, mixed with water in a high-speed "Colcrete" mixer*.

During this process the rock absorbed a further 850 lb. per sq. ft. (35 kg./m.²) of tunnel surface. By this means it proved possible to introduce large enough compressive stresses in the concrete ring, as was confirmed by measuring the contraction of the perimeter. Strain gauges fixed at numerous sections indicated that the stress distribution was not uniform over the entire ring, but these variations are evidently smoothed out later as the internal pressure is applied.

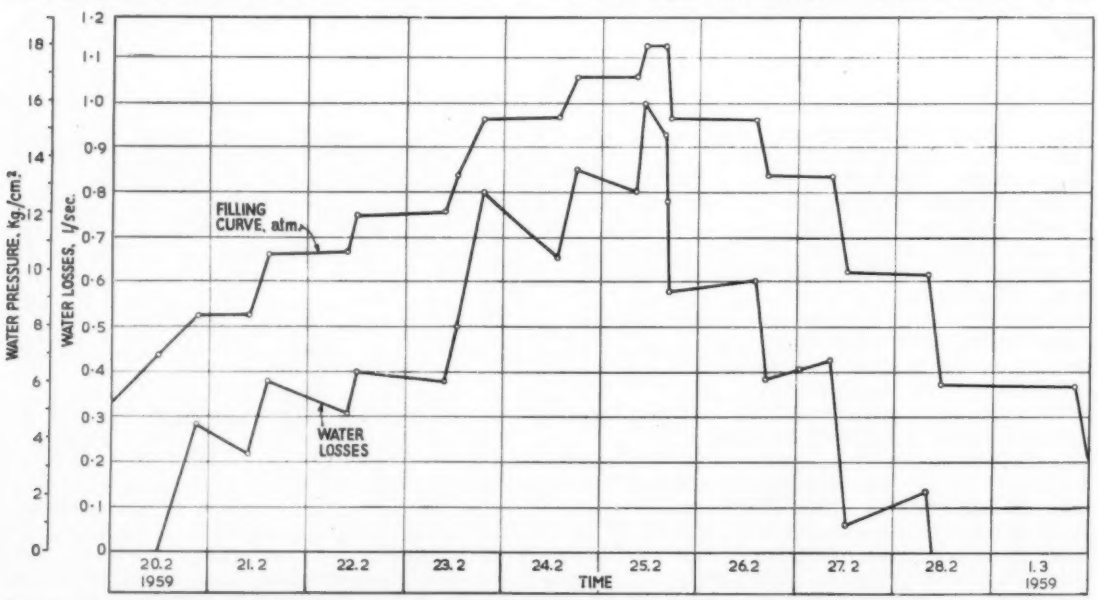
The Reisach tunnel was filled again in the summer of 1955 and remained in service without interruption until February 1959; during this period the Reisach plant operated as a simple pumped-storage station. The arrangement of the intake at the Rabenleite high-level reservoir (see page 317) permitted fairly accurate measurements to be made during shut-down periods. These regular tests showed that the leakage in the tunnel and the shaft certainly did not initially exceed 25 g.p.m. (2 lit./sec.); during later measurements the tunnel proved to be almost completely watertight and inspection of the tunnel in February 1959 showed that it was in surprisingly good condition. It was decided, nevertheless, to utilise the shut-down period required by the connection of the Tanzmühle station to carry out a brief grouting operation; its purpose was to make up for any possible loss in prestressing caused by plastic deformation of the rock formation.

The entire tunnel system was filled again in May 1959 and operations started first at Reisach and later at Tanzmühle. It was found that the pressure surges due to simultaneous shut-down of both stations interfered only very little with each other. The leakage of the two high-pressure tunnels could once again be determined accurately; its value varied around 16 g.p.m. depending on the water level in the storage reservoir.

The engineering success of the Reisach tunnel is accompanied by unusually large economic advantages. An attempt has been made to relate, for these particular geological conditions, the possible output at various internal pressures with the corresponding construction costs. The result is very surprising (Fig. 11). and shows clearly the economic advantage of the method actually used.

Provision for the junction with the Weinberg tunnel had already been made during the construction of the Reisach shaft. At approximately one-third of its

* The method described above was developed by Ing. Hautum, Head of Construction Department of the Energieversorgung Ostbayern A.G. in co-operation with Kunz & Co., Munich.



Increasing pressure: When pressure is kept constant for a time, water losses reduce due to gradual saturation of surrounding rock.
Decreasing pressure: When pressure is kept constant, water losses increase slightly. This can be explained by water seeping back into the rock which has been drained during the decrease in pressure.

Fig. 12. Water losses in Weinberg tunnel during pressure test

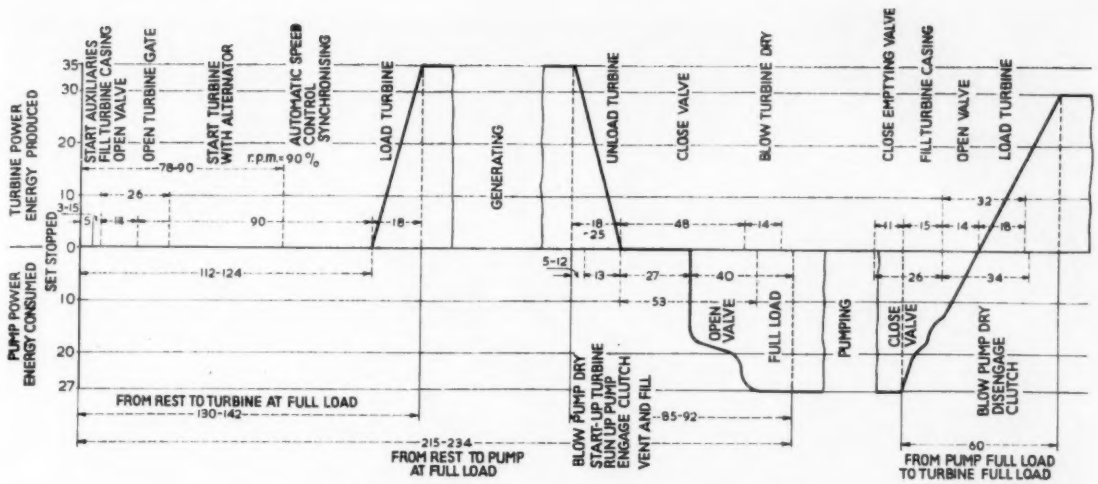


Fig. 13. Operating diagram for Reisach power station

height, a short branch 160 ft. (50 m.) long, had been driven in the direction of the Tanzmühle plant. This was lined and then closed at the front third of its length by means of a reinforced-concrete plug. The actual tunnel was then constructed together with the second stage of the Tanzmühle station and thus did not interfere in any way with the operation of the plant already completed.

When starting excavation of this high-head tunnel (maximum operating head 610 ft., 18 atm.; diameter 11 ft. 8 in., 3·5 m.; minimum rock cover 170 ft., 50 m.) sufficient information had been obtained on the rock formation from the construction of the Reisach and Eulengrund tunnels. In particular, the experience gained with the former could be utilised again, and the technique of prestressing was further improved. It was decided therefore to use for this tunnel also a simple concrete lining prestressed by grouting. The tunnel was constructed by the full-face method using modern systems of protection such as rockbolting and sprayed concrete. Only the section passing obliquely through a 35 ft. (10 m.) thick fault zone required heavy supports. The final part immediately before the previously completed junction with the Reisach shaft was fired with particular care, using smaller charges and millisecond firing. A horizontal borehole some 35 ft. (10 m.) long had previously been drilled through the remaining rock plug in order to check that the already completed lined section was not under pressure from the high-level reservoir. This precaution was taken since the Reisach tunnel remained in service throughout the construction period and the pressure on the concrete closure plug was nearly 1,200 tons. The two tunnel sections were then joined together without appreciable height or lateral deviations. The plug was found to be completely watertight and no seepage had taken place round it.

During the construction of the tunnel an auxiliary shaft with a section of $6\frac{1}{2} \times 6\frac{1}{2}$ ft. (2×2 m.) had been sunk close to the high-level reservoir. A borehole drilled in the course of a geological survey of the tunnel alignment was used for this purpose, and the excavated material was dropped down the borehole. This auxiliary shaft was used to provide access for the material required during grouting, which took place at the same time as the assembly of the pipeline at the front end of the Weinberg tunnel.

It was considered essential to maintain a minimum lining thickness of 16 in. (40 cm.) in order to ensure satisfactory placing of the concrete. In this connection special attention was paid to avoiding any rapid changes in cross section which gave rise to cracks due to the notch effect. All large overbreaks were therefore carefully filled with concrete, irrespective of whether they had been accidental or were required for constructional work. Concreting was done in sections 45 ft. (13·5 m.) long, with the invert completed in advance of the remainder. The usual grouting of the contact joint was followed by the actual prestressing grouting according to the method developed for the Reisach project and preceded again by washing out with water to which a surface-tension reducing agent had been added. The cement absorbed by the rock per unit length of tunnel was on the average 105 lb. per ft. (160 kg. per m.), that is about 2·9 lb. per sq. ft. (14·5 kg. per sq. m.) of concrete surface.

During the same period the pipeline in the lower sections of the tunnel was assembled. This solution had been adopted here in preference to a steel lining backed by concrete which would have cost approximately the same amount but would have taken longer to complete. It had been established by a preliminary geological investigation that the rock was certain to be completely stable in the region where a pipeline was to be used. The surface of the tunnel only required protective torcreting and bolting in certain places. The pipeline was 11 ft. 8 in. (3·50 m.) in diameter and was made from UB 36 steel; it extended some 675 ft. (200 m.) into the rock until the cover reached a thickness of 170 ft. (50 m.). The pipe was anchored at this point by concreting in a length of 65 ft. (20 m.) which had had rings welded to it. The pipe is supported every 104 ft. (31·3 m.) on movable supports, and is closed on the water side by a valve located immediately in front of the manifold. Any changes in length due to temperature variation and the closing of the valve are taken up by an expansion joint on the water side of the emergency gate. Access to the pipe and therefore to the tunnel is through an adit which had been used during the construction of the Eulengrund tunnel. For this purpose a small chamber was excavated along the tunnel axis and a

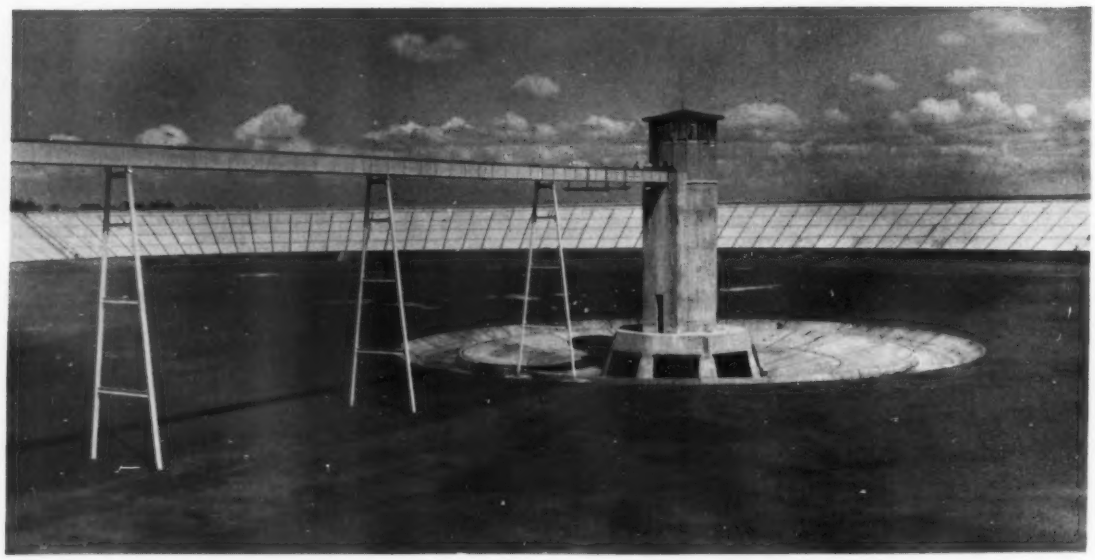


Fig. 14. The Rabenleite reservoir, when empty, showing the intake tower

length of pipe, 33 ft. (10 m.) long, was arranged to slide sideways, thus giving access to the full cross section.

Before placing the tunnel into service it had to be subjected to an initial pressure test of 610 ft. (18 atm.), 1·3 times the static head. After completion of the assembly and grouting operation, the auxiliary construction shaft was sealed after providing two pressure-tight airlocks. A vent pipe 5 in. (125 mm.) internal diameter was then passed through this lock to the highest point of the tunnel near the plug. The tunnel was closed on the water side by spherical bulkheads in the branches of the manifold, while on the downstream side the plug at the connection to the Reisach tunnel acted as a seal. The Weinberg tunnel was then filled through a pipeline from the Eulengrund tunnel until the water level of the Kainzmühle dam was reached. The water temperature was only +2°C., whereas the temperature of the rock was +11°C.; this difference alone resulted in a reduction of the prestressing in the lining by some 450 lb. per sq. in. tangential stress. After two days the water had warmed up to about 4°C. and the small vent pipe was then filled to expand the tunnel. This was done twice a day in steps of about 30 ft. (1 atm.). Since the cross section of the vent pipe was very small compared with the water volume in the tunnel, this formed an extremely sensitive method for determining the water leakage and all other effects. Taking into account the elastic compression of the water and of the tunnel, as well as the elastic expansion of the unrestrained vent pipe, it was possible to determine the modulus of elasticity of the grouted rock, knowing the characteristics of the concrete. A value of $2{\cdot}8 \times 10^6$ lb. per sq. in. (190,000 kg. per sq. m.) was obtained. When the test pressure of 610 ft. (18 atm.) head had been reached (for general arrangement of pressure test see Fig. 12), the water leakage of the 5,000 ft. (1,500 m.) long concrete tunnel was found to be not more than 14 g.p.m. (1·0 lit./sec.) and was already decreasing. The leakage did not show a linear variation with pressure but followed a square law, with a reduction of the leakage during periods when the pressure was maintained constant (Fig. 12). During the expansion of the tunnel, continuous measurements were taken on the concrete lining and the rock at two sections. The results obtained with hydraulic pressure cells, Type Glötzl (see ATM, No. 265, February 1958) which also indicated secondary stresses and therefore reproduced the actual conditions in the concrete, appeared to be very reliable.

Following the pressure test, the tunnel was emptied

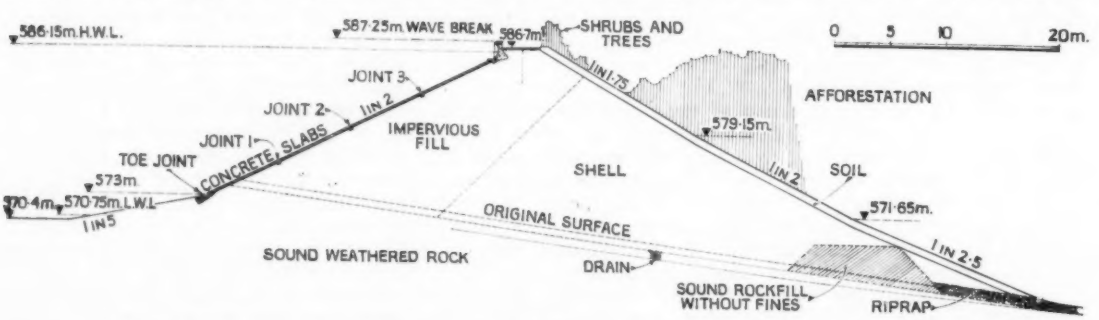


Fig. 15. A typical section through the Rabenleite high-level reservoir embankment

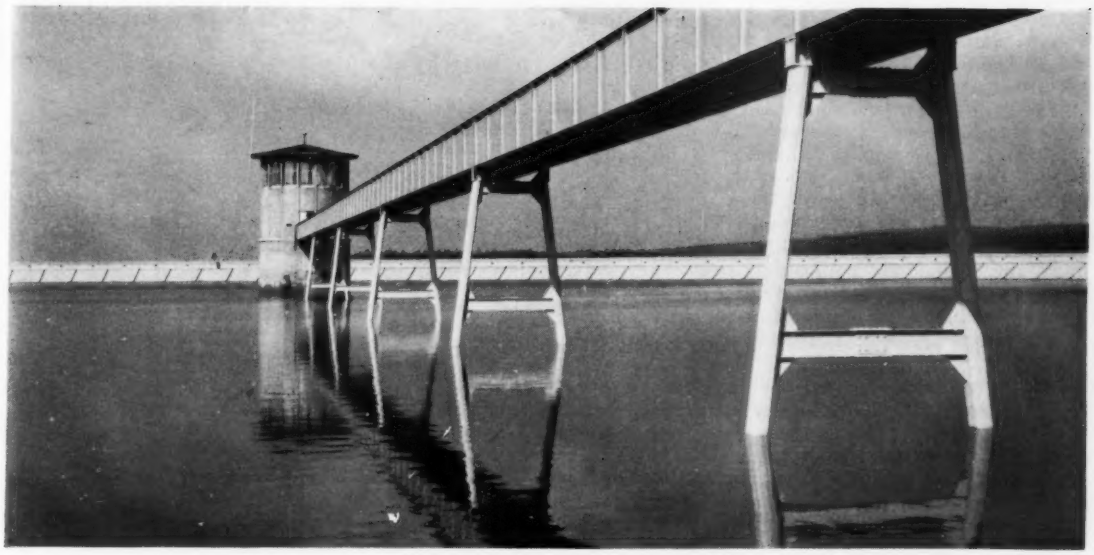


Fig. 16. A view of the Rabenleite reservoir containing storage water

and inspected again; no cracks or traces of water seepage were found. It was nevertheless considered necessary to carry out a further series of grout injections in order to compensate for the slight loss in precompression due to the plastic deformation of the rock during the first pressure application. Finally, a reinforced gunite ring was placed in the transition between steel pipe and tunnel as well as in the adjacent fault zone; the internal diameter had been increased there to allow for this.

The plug was then excavated to connect the tunnel with the high-level reservoir and the Reisach shaft which had been drained in the meantime. The pumped-storage scheme began to operate according to its final operating schedule in August, 1959.

The Eulengrund tunnel (Fig. 2) is the longest pressure tunnel in the Pfreimd scheme, 9,230 ft. (2,770 m.), but is of much less engineering interest than the Reisach and Weinberg tunnels. It has an internal diameter of 11 ft. 8 in. (3·50 m.) and is subject to relatively small pressures over most of its length; only at its lowest point nearest the Tanzmühle station does the pressure reach a maximum of 170 ft. (5 atm.) including operating allowance. The Eulengrund tunnel was constructed in 1954/5 and connects the Kainzmühle lower reservoir with the Tanzmühle power station. In order to protect the tunnel against high pressures a simple surge tank of 37 ft. (11 m.) diameter was constructed close to the Tanzmühle station (Fig. 2). The tunnel has been in service since 1955, being used in conjunction with the Francis turbine at Tanzmühle; it only began to fulfil its real function, however, when the Tanzmühle pumped-storage set started up. The tunnel was emptied in 1956 and in the early summer of 1959 for several short periods; nothing of importance was found during these inspections.

Rabenleite High-Level Reservoir

The Rabenleite high-level reservoir (Fig. 14) forms the focal point of the whole pumped-storage scheme; pumps and turbines at both the Reisach and the Tanzmühle stations operate in conjunction with this reservoir. It was constructed in the years 1952–1955, at the same time as the Reisach station and tunnel, and lies on the Rabenleite, a level hill-top close to the river. An area of 110,000 sq. yd. (100,000 sq. m.) was stripped to an average depth of 17½ ft. (5·3 m.). The material obtained in this way included weathered gneiss granite to a thickness of 7 to 10 ft. (2 to 3 m.), and the decision was made to build an earth embankment with it. A ring-shaped dam was thus constructed, according to the natural contours, employing a balanced material transport system. Some 0·4 cu. ft. of material had to be moved for each cubic foot of useful storage capacity.

The weathered zones were highly suitable for use in the impervious core because of the low degree of compaction required and also because of their ability to withstand frost. The material had a high shear strength; the angle of repose was 41°. The average density after compacting was 0·053 ton per cu. ft. (1·96 ton per cu. m.), with a void ratio of 26%. There was no difficulty in separating the weathered material and the sound rock either during excavation or during dumping; arrangements were in fact made to vary the material used in order to suit the prevailing weather conditions. The shape of the impervious core (Fig. 15) made it necessary to raise the downstream dam face ahead of the other face. This part was compacted mainly with a dragline tamping plate; the compaction was increased towards the dry dam shoulder, and generally speaking the sounder rock material was placed on the air side in accordance with the stress distribution. The layer thickness which still gave satisfactory compaction varied between 18 and 32 in. (45 and 80 cm.). The material was placed with the optimum water content as recommended by Proktor (11%); this required an addition of 5·5–8% water to the natural moisture content. Compaction was carried out mainly by vibrators and by dragline compactors. The total dam volume was nearly 22×10^6 cu. ft. (600,000 cu. m.).

While the embankment was being constructed it was decided for economic reasons to increase the useful capacity of the reservoir by almost one-third to 55×10^6 cu. ft. (1,500,000 cu. m.). This was done by

cutting down the freeboard and the unusable water volume, and also by lowering the reservoir floor using a slope of 1 in 5, thus ensuring optimum utilisation of the embankment constructed.

The dam section itself provided a seepage line of very favourable shape. It was clear, however, that additional sealing was required at the base and in particular on the slopes in view of the mechanical and structural loads in this region. It was essential to ensure stability of the impervious core during rapid drawdown which the pore-water pressure was unable to follow. The slope was therefore protected by concrete slabs resting on previously prepared strip foundations. A sealing layer is held in contact with them by the water pressure. The unreinforced slabs measured 23 ft. 4 in. × 23 ft. 4 in. × 8 in. and are arranged in contact with each other in four horizontal rows. A toe was provided at the transition from the 1 in 2 to the 1 in 5 slope to prevent the slabs from slipping down. The slabs were cast by means of a specially constructed paving machine which was preceded by a compactor and followed by a working platform for the finishing operation. A plasticiser was added to the concrete to increase its resistance to frost damage; the surface was protected against the effects of sunlight. The upper edge of the top row of slabs carries a wave breaker because of the reduction in freeboard to only 1 ft. 10 in. (55 cm.). The concrete specification, a bending strength of 600 lb. per sq. in. (40 kg. per sq. cm.) and practically complete imperviousness to water at 75 lb. per sq. in. (5 atm.), could be adhered to.

Surfaces with a shallow slope as well as the reservoir floor itself showed a variation in natural permeability; they were carefully levelled and covered with a bituminous "mammoth skin" paving. This consisted first of a layer of glass wool as protection against moisture, followed by leatheroid board laid in a bed of poured and rolled hot bitumen to improve the tensile strength. A poured asphalt layer of special composition forms the main component of the skin. By applying 2·4 lb. per sq. ft. (12 kg. per sq. m.) it was possible to achieve a minimum thickness of 0·56 in. (14 mm.). Filler was added to the asphalt in the proportion of 50% for the practically horizontal areas, and 60% in areas having a gradient of 1 in 5. The surface was sanded later to stop any incipient formation of cracks.

The intake structure, with its concrete funnel and silt trap, passes through the floor seal at a safe distance from the toe of the dam. The top of the tower contains the operating gear for the cylindrical gate which closes the radial inlets to the shaft (Fig. 14). and is operated remotely. The winch house is reached over a footbridge constructed from steel girders. The air side of the dam was seeded and planted immediately after completion to prevent erosion by rainwater.

If the total construction cost based on 1952 prices is divided by the useful storage capacity of the reservoir, a specific cost of 6·65 DM. per cu. m. (£13 per 1,000 cu. ft.) is obtained.

The high-level reservoir has now been in operation for four years in conjunction with the Reisach station and it has become possible to draw certain general conclusions concerning the structure. The solution adopted, which had been selected to give minimum cost, has proved very successful. The high-level reservoir was used extensively during the first winter and was subject to extreme weather conditions which it withstood very satisfactorily. The seepage water is collected in drains and checked regularly; it has varied around 65 g.p.m. (5 lit. per sec.) and clear water only has been observed. The total water losses of the reservoir shortly after its completion were estimated on several occasions as 200–270 g.p.m. (15–20 lit. per sec.), but no reliable estimate of the evaporation losses was possible. The sealing skin at the floor of the reservoir has proved particularly satisfactory. Because of its elasticity it was able to maintain a continuous seal even when excess water pressure below caused some parts of the floor to rise up; it could also adjust itself to unevenness due to the washing out of the finer constituents. Damage was confined to a strip 30 ft. (12 m.) wide on the 1 in 5 slope and was caused

Fig. 17. A view of the Rabenleite high-level reservoir and surrounding landscape

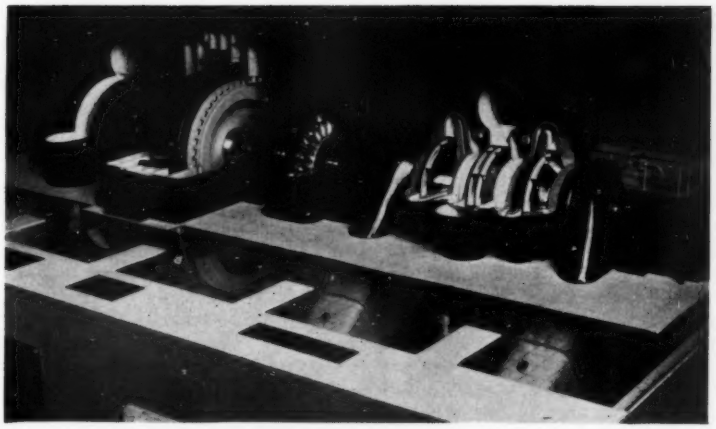


Fig. 18. A model of a Reisach pumped-storage set

by ice floes which dropped on it during winter; due to variation in water level these ice floes tended to build up on this slope to a height of some 6 ft. (2 m.). The damage was readily repaired by simply applying a new layer, without any interruption in the operation of the scheme. When the Reisach plant was taken out of service to allow the Tanzmühle station to be connected up, the shut-down period was utilised to reinforce these areas with a sheet-steel lining 0·012 in. (0·3 mm.) thick. This promises to prevent mechanical damage in view of the results achieved with a number of experimental areas in the reservoir which have been exposed to these conditions for several years. Maintenance work was also carried out on the concrete slabs, several of which showed cracks, especially in the lowest row. These cracks were scraped out and filled by high-adhesion concrete. Any hollow areas found were filled by pouring in grout. The vertical joints, which had receded in many places after the water level had been lowered, were sealed by means of bituminised asbestos string.

Electrical and Mechanical Equipment

It is impossible here to give more than a few brief details of the electrical and mechanical equipment in the Reisach and Tanzmühle stations. Fig. 18 shows a model of one of the Reisach pumped-storage sets. The Tanzmühle machine is a similar unit but has no starting turbine. Fig. 13 gives the various elements of the operating sequence plotted against time. The voltage at the alternator terminals is 10·5 kV; power is transmitted from Reisach or Tanzmühle to the nearest grid feeding point, a distance of 10½ miles (17 km.), over a 110 kV transmission line. The plant not only supplies peak load but has to provide also a considerable instantaneous reserve in the case of a grid failure; it has therefore been considered essential to install an extensive and complex protective system.

The entire hydraulic equipment, including the turbines, pumps and valves in the power stations and the Rabenleite intake tower, has been constructed by Voith G.m.b.H., Heidenheim. AEG have supplied the two alternators in Reisach power station and are delivering the third during the present year. This firm has also equipped the 110 kV switchyards at Reisach and Tanzmühle. The two alternators in Tanzmühle station and also the two alternators in Trausnitz station were built by Siemens-Schuckert AG, who also supplied the electrical automatic gear throughout the scheme. The transformers, one of which is yet to be delivered, were built by Brown Boveri.

The chief contractor for the construction works was Kunz & Company, Munich, in collaboration with Hochtief AG and Polensky & Zöllner and other local companies.

Summary

In the years 1952/5 and 1957/9 the Energieversorgung Ostbayern AG has constructed a pumped-storage scheme on the River Pfreimd near the Oberpfälzer Forest; its most interesting constructional features are the Reisach and Tanzmühle tunnels and the artificial high-level reservoir Rabenleite. These structures were constructed at a relatively low cost and have proved very satisfactory in service, some of them over a number of years. The overall efficiency of the Reisach system with simple pump storage and optimum operating conditions has reached the exceptionally high value of almost 75%, a figure which reflects not only the high quality of the equipment but also the high standard of civil-engineering design. In conclusion it should be mentioned that the owners have recently published a book dealing with the Reisach station*, and a description of the Tanzmühle plant is to follow shortly. This book has provided most of the information for this article.

* "Das Pumpspeicherwerk Reisach-Rabenleite." Published by Energieversorgung Ostbayern AG, Regenburg. (Reviewed in WATER POWER, August 1958, p. 306.)

From page 302

Depletion of reservoirs.

In addition there is a very powerful matrix interpretive scheme with which programmes can be easily constructed. Such programmes have been written to make stress analyses of concrete arch dams.

Available at the IBM programme library at Wigmore Street, London, W.1, are the following, suited for the IBM 650 computer:—

Cut and fill.
Moment distribution.
Analysis of laterally loaded piles.
Water surface profile.
Circular culvert.

Some of the programmes at the Ferranti London Computer Centre library are listed below:—

Turbo-alternator harmonics analysis.
Regulation and efficiency of three-winding transformers.
Power-system load studies.
Power-system network reduction.
Differential equations related to flow through a hydraulic valve.

It can be surmised, therefore, from the symposium and from the information supplied by the computer manufacturers that electronic computers are becoming a great help to water-power engineers, and the tendency is that they will become indispensable in the future.

Book Reviews

Hydrology. C. O. Wisler and E. F. Brater. Chapman and Hall Limited, 37 Essex Street, London, W.C.2. Second edition. 408 pp., 136 ff. Price: 74s. net.

This book, which has been extensively revised, gives a good overall grounding in hydrology. It builds up from basic principles and the terminology used is clearly explained. Much new material has been added and two new chapters have been introduced, one dealing with hydrology in semi-arid regions and the other on the effects of snow melt in establishing stream flow characteristics. The chapter on floods discusses methods for the determination of the magnitude of floods and their frequencies, and includes a calculation based on the unit hydrograph method, which the authors regard as dependable and basically sound. The various illustrations, tables and statistics in the book are all data obtained in the United States of America.

12e Enquête sur l'Equipement Electrique—12th Survey of Electric Power Equipment. Published by Organisation for European Economic Co-operation, 8 in. × 10·5 in., 134 pp., 9 graphs. Distributed in United Kingdom and Crown Colonies by H.M. Stationery Office, P.O. Box 569, London, S.E.1. Price 10s.

This report is divided into two parts: I. Plant development in the electricity supply industry, which gives the results of the 3rd survey of the Electricity Committee, and Part II, which deals with the results of the 12th survey of the Machinery Committee on heavy equipment. The four sections of Part I (thermal plant, nuclear plant, hydro plant, and transmission lines) are supplemented by two annexes—(a) statistics and forecasts for each member country relating to the class of equipment considered; (b) names and characteristics of new plant: thermal (over 40 MW), hydro (over 10 MW), transmission lines (over 220 kV), gas turbines and nuclear power stations. Part II covers the deliveries effected, and the orders in hand on January 1, 1950, prime movers, alternators and transformers being dealt with in separate tables. A chapter on general considerations reviews the trend of production. From Table F, which gives the characteristics of units manufactured in member countries, we learn that while the maximum rating of steam turbines grew from 110 MW in 1951 to 550 MW (a British unit) in 1959, the corresponding figures for water turbines remained stationary at 150 MW; the trend in alternators follow the same pattern. Tables H to P in annex 2 to Part II analyse the deliveries of the various classes of heavy equipment by producer countries.

Kapesní anglicko-český a česko-anglický technicky slovník (Pocket-size English-Czech and Czech-English Technical Dictionary). By Josef Novák. Published by Státní nakladelství technické literatury (State Publishing Office for Technical Literature), Spálená, 51, Prague 2. 4 in. by 5·1 in., 496 pp. Price in Czechoslovakia, bound, Kčs. 22·90.

A first edition in 20,000 copies of a dictionary of this kind is the obvious proof of an extensive demand, and appears justified by the growing importance of technology in an economy which is supported on the export side by large engineering undertakings. This neat little volume, with over 10,000 terms in each of its two parts, is a considerable enlargement of the dictionary published by the author ten years ago on behalf of the Škoda Works. Compiled in the first place for mechanical engineering and metallurgy, it also includes the most important terms occurring in other branches of engineering, and the terminology of water-power developments is well represented. The phonetic pronunciation appended to each term of the English-Czech part is very good, and should prove very useful to Czech users, for whom the work is primarily intended. The Czech-English part will be found quite helpful to the English user when dealing with drawings and diagrams appearing in Czech technical publications or—subject to having some knowledge of the language at his command—when reading such publications. Conversion tables and 11 pages of English and American abbreviations are appended. Print, paper and binding are excellent.

Kraftwerke Zervreila (The Zervreila Hydro-Electric System). Published by Kraftwerke Zervreila A.G., St. Gallen, and printed by Buchdruckerei Ostschweiz A.G., St. Gallen, 1959; 8 in. by 12 in., 42 pp., 37 ff.

In addition to a detailed description of this interesting hydro-electric system (see WATER POWER, March 1960, p. 122), this publication contains magnificent photographic illustrations and diagrams, some of them in colour, of the works and installations. The contrast between the half-tones showing the Vals Valley and the Zervreila hamlet before construction work started, and the colour photograph of the completed Zervreila dam and power station is particularly impressive.

Modellversuche für Hydraulische Maschinen (Model Tests for Hydraulic Machines). Published by the Institute for Hydraulic Machines and Installations of the Federal Technical University, Zurich; 11·5 in. by 8 in., 31 pp., 14 ff. Price in Switzerland, paper wrappered, Swiss Fr. 4.

This brochure is a reprint of the papers which were read at the meeting held jointly at the Federal Technical University on February 13, 1959, by the Institute for Hydraulic Machines and Installations, the Swiss Association of Electrical Engineers, the Swiss Water Association, and the Mechanical-Engineering Section of the Swiss Association of Engineers and Architects. It contains the following papers: Model tests for hydraulic machines and their application to reception tests, by Professor H. Gerber; Comments of an actual operator on the draft of an international code of regulations for the testing of small-scale turbine models, by M. P. Bourguignon; Present-day practice in model tests for turbines in lieu of reception tests, by Dr. R. Dziallas; Forecasting the behaviour of turbines on the basis of model tests, by Dr. Stanley P. Hutton; Considerations on contractual cavitation tests effected on small-scale turbine models, by M. M. Fauconnet; Remarks on the draft of rules for reception tests on models, by A. Pfenninger. The brochure ends with excerpts from the discussions which concluded the meeting.

Loans at Work. This booklet issued by the World Bank, illustrates a wide variety of projects that are being assisted in various parts of the world. It is divided for convenience into different regions, each illustrated by a map which shows by symbols the type of loan made to each country. Loans for hydro-electric schemes figure prominently.

The World Power Conference

A commentary on the Sectional Meeting of the World Power Conference held in Madrid recently

AMONG the 1,356 participants in the sectional meeting of the World Power Conference held in Madrid in June, there were naturally many engineers exclusively concerned with hydro-electric development; and looking back on the 164 papers and the 152 contributions to the discussions, it might be suggested that they alone could view the future with optimism—for alone among the engineers concerned with power supplies they did not encounter any potentially disturbing trends towards a complete rearrangement of the basic systems they had evolved to carry out their respective functions. Transmission engineers, for example, heard that it was in many cases cheaper to transport solid fuel by "first-class railway" than it was to generate at the pit head and carry the energy by overhead electric lines. The pipeline, too, for both oil and natural gas was seen as a growing competitor to the electrical transmission of energy, when either of these fuels was available. Steam-power-station engineers heard of a new range of equipment involving supercritical pressures and temperatures, bringing with them new and possibly difficult problems. Nuclear-power-plant engineers heard sharply critical surveys of the future of nuclear power, not in respect to its ultimate practicability, but in regard to the cost per unit and the date at which this cost would become competitive with ordinary current from conventional sources.

The hydro engineer, on the other hand, heard nothing but encouragement for him to produce, in his traditional way, modified gradually as the years progress, as much energy as he could from this non-wasting asset. And he heard, moreover, from many countries of new evaluations of the amount of hydraulic energy available, always greater than previous estimates. He heard about new methods of prospecting for hydraulic energy which promised to provide him with reassessments of the economic feasibility of many projects hitherto regarded as not likely to be worthy of economic development. And he also heard of methods whereby the hydro-electric potential in any given country could be more economically integrated with the remainder of the energy resources. In these papers, particularly, there was continuous tribute to the flexibility of most hydro-electric projects and to the invaluable contribution they were able to make by way of improving the efficiency of other types of generating plant.

Investigating Hydro-Electric Resources

The general reporter on the section on "Methods of Investigating Sources of Hydro-electric Energy" gave a useful summary of the present state of knowledge of hydro-electric resources. In the countries of "old" Europe, hydro-electric development of rivers has advanced ceaselessly for a hundred years, and inventories of river power possibilities, in stretches harnessed and capable of development have been compiled with fair exactitude. Besides their increasing accuracy, these inventories always indicate an increase of variable potential when technical progress makes possible solutions previously regarded as unfeasible or uneconomic.

As progress extends in large mainland Asiatic countries, power and agricultural needs lead to a better knowledge of river characteristics and their vast hydro-electric possibilities, but "we have not heard that any approximate general correlative inventories have been drawn up." Some island Asiatic countries, such as Japan, Formosa, and the Philippines are an exception, and so are the mainland countries of the near East, the hydro resources of which are the subject of very advanced studies.

In North America, official agencies and private enterprise have obtained a perfect knowledge of the rivers, except for the sparsely inhabited regions of Alaska, Northern Canada, and Southern Mexico, where hydro investigation has been sporadic. Central America lacks inventories, since the easy use of liquid fuel and the scanty industrial development have caused hydro studies to be neglected. The problem is different in South America and Australia, where industrialisation is concentrated in very small areas, and yet an approximate knowledge of river development is of immediate interest for absorbing immigrants from over-populated countries.

There remains the fabulous possibilities of the African rivers, which have already been the subject of important projects and of some isolated developments. No inventories exist for these rivers, except in the Mediterranean countries and in the Union of South Africa.

This summary of world knowledge of hydro-electric potentialities, prepared by Señor Pedro Martínez Artola, sets the scene for the hydro-electric papers of the conference. From among the papers in this section perhaps the most interesting was that from Mr. T. Ingledow, of International Power and Engineering Consultants Limited, of British Columbia, Canada. It showed how very rapid surveying could be carried out over the area of the Peace and Liard rivers in Western Canada, covering the very large area of 84,000 sq. miles. Some 170 potential sites for dams were investigated, together with a preliminary appraisal with estimates of the relative merits between alternative sites and between combinations of sites, all this work having been completely finished within a total period of only 18 months.

The first review was guided by the three basic requirements for a hydro-power assessment: water supply, horizontal and vertical survey control, and suitable dam sites. Approximately two months were required to collect and assimilate the available data, and to prepare a programme for field reconnaissance. The equipment employed included a preliminary set of air photographs to link up the missing map data, and then a plan for barometric levelling to correlate roving barometer readings with a standard base barometer. A Bell type G.1 helicopter with an operating radius of 60 miles was employed, and also float-

equipped Beaver and Cessana aircraft for the main moves from one camp to another.

By a series of 49 carefully planned sites, complete survey material was obtained, and as a result of this very careful planning, those responsible were able to arrive at a scheme of development of hydro-electric potential that would prove reasonably attractive under present-day economic conditions, and also to present the maximum capabilities that might in the future warrant consideration, should economic trends so change as to favour higher-cost hydro power development. Perhaps the special feature of the paper was the indication of how great an accuracy can be achieved nowadays by aerial-survey methods of various kinds.

Artificial Rainmaking

Hydro engineers have always looked with interest on rainmaking possibilities, and a paper by Mr. F. W. G. White, of the Australian Commonwealth Scientific and Industrial Research Organisation, showed how rainmaking and the prevention of evaporation have increased the water resources in Australia. In the Snowy Mountains area cloud seeding with silver iodide has been shown to produce an economically significant increase in precipitation over a definite area, and Mr. White's paper gave for the first time the results of five years' experience.

Seeded and control areas were established, each of 750 sq. miles in extent. Seeding was carried out by burners on the wing tips of aircraft, each aircraft being fitted with two burners dispersing 550 g. of silver iodide in an acetone solution per hour, from each burner. The figures show an increase with a most probable value of 20% in the ratio of precipitation of rain clouds in the target area, compared with those in the control area.

Mr. White says that there are grounds for believing that the average precipitation over a catchment area could lead to important secondary effects. For example, the cloud base is likely to be lowered, and loss by evaporation from water drops between clouds and the ground is likely to be reduced. With increased total precipitation, the proportion running off might also be expected to improve.

The paper from Australia also gave the results of important experiments on the reduction of evaporation from storage water. The normal annual evaporation in Australia was said to be more than 50 in. per annum in most parts and in some parts higher than 100 in. per annum. The use of monomolecular films has been tried out in Australia by the Chemical Research Laboratories of the Commonwealth Scientific and Industrial Research Organisation, and if a monolayer of hexadecanol, the chemical most suited for these experiments, could be maintained on a water surface, the evaporation could be substantially reduced. Rafts were provided which carried the hexadecanol in containers with gauze sides. When correctly used on storages which were not subject to the formation of large waves, these rafts had made it possible to maintain an effective hexadecanol film at relatively small cost, and the evaporation losses in many locations had been reduced by a quarter, or more. Other methods of applying the chemical have also been tried out and it is expected that further practical applications of this method will be employed in the future to assist in conserving the relatively limited water resources of the Australian continent.

The General Reporter rather unexpectedly added the comment that the number of papers presented to the section had been very small, probably owing to the fact that investigation of hydro-electric reserves is a question "nearly exhausted" in almost all the countries represented at the World Power Conference. This view was brought out by inference in the discussions, where little that was new by way of principles emerged, but a great deal of detail was added to the papers and the general report.

Exploitation of Hydro Power

The section on "Efficiency in Production and Utilisation of Hydro Power" had as its General Reporter Senor G. Millet Maristany, and he at once admitted that with the wide scope of this subject it was difficult to find a means of channelling the discussion along any one predetermined path.

There were, however, groups of papers on the results that could be achieved by rationalising operational methods. There was considerable interest, now that hydro power stations in many parts of the world are gradually being incorporated into larger and larger systems, in the evolution of principles for economical running of both hydro and thermal plant. In the hydro field, it was shown that the main operational problem is to co-ordinate, on a system level, the control of water consumption in reservoirs, bearing in mind that the risk on the one hand was the wastage of water by spilling over after heavy rains, and on the other hand excessive use of energy which could produce a shortage at a later period when meeting a normal demand.

However, no conclusions were reached, since it soon became apparent that no two hydro systems had anything like the same characteristics. For example, a Spanish engineer, in conversation with the writer, said that in Spain the overriding consideration was always that of making maximum utilisation of the water in the "flashy" river systems for irrigational use, and that power generation always took second place.

From Sweden a paper by Messrs. S. Stage and Y. Larsson, attempted to evolve a "basic rule curve" so that the exact moment when thermal plants should start to take over the load, in relation to the amount of storage in the reservoirs of the hydro plants, could be determined. They said that when a dry period is faced, running up of the thermal plants should be delayed as long as possible because the water situation might change, but on the other hand, thermal plants must be given sufficient time in order to be able to make good the deficit of energy during the dry period, in case it should happen to be exceptional. They said that these aspects were mutually contradictory, and this led them to evolve their rule. This was roughly as follows. The storage-time diagram was divided into two parts, known as the primary zone and the minimum zone. When the amount of storage was within what was known as the primary zone, the discharge drawn from it was determined by the rate of flow required in order that the hydro plants might be able to supply the whole load. However, peak loads could be supplied from thermal plants if necessary. This is known as the primary discharge, but when the storage level was within the minimum zone, the thermal plants should be run at full capacity throughout the twenty-four hours. The discharge drawn from the storage was then confined to the rate of flow needed to deal with the rest of the load, and this was called the minimum discharge.

The authors describe how the basic-rule curve was determined. The minimum zone was established in such a way that the minimum discharge, mentioned above, could be drawn from the storage even during the worst period of water shortage. To define this "worst" period, they based their calculations on the worst situations recorded during the last 25 years.

Papers from Canada, Yugoslavia, Portugal and Spain also showed how methods are being developed for the more rational exploitation of hydro-electric reserves. It was significant in the discussions that the main burden of the contributions was towards more rational exploitation of hydro-power resources of all kinds, showing, it might be said, a much more scientific approach to the problem of energy conservation than has been apparent at previous World Power Conferences.

Several speakers mentioned the use of computers to simplify the very involved mathematical calculations necessary for proper evaluation of the many complex varying quantities in planning hydro power operation.

Among the papers dealing with improved utilisation of hydro power resources was one by Professor P. G. Shenguelia, of the U.S.S.R., on means for reducing the head losses in the regulation of run-off. Professor Shenguelia said that the regulation of run-off usually involves a deterioration of the reservoir with a resultant reduction in the head of water available for the power station. These losses could amount to between 8% and 27% of the total annual production of the hydro power stations, to mention typical Russian figures. He thought that this subject had not been sufficiently explored, and he said that in constructing storage dams on rivers two goals are generally kept in view—the providing of head and the regulation of run-off; but in a number of cases in regulating the run-off, loss of power so caused proved to be higher than the additional power obtained through the utilisation of the extra run-off resulting from regulation.

A method whereby this difficulty could be avoided would be to install an additional foot-of-the-dam or canal-type power station upstream from the regulation reservoir. This station could be so placed as to take advantage of the drop from the upstream reservoir, or it might even be an underground station and could be provided with a tunnel which would carry the tailwater to the low level of the reservoir. Another solution was also proposed: that of raising the lower-stage dam and planning the upstream station so that the tailwater-tunnel exit is at the backwater height of the reservoir with its increased height of dam.

Pumped Storage

The section on pumped storage produced four papers, two from Poland, one from Germany and one from Switzerland.

One of the Polish papers by Messrs. K. Jackowski, E. Koban and A. Laski, described a plan for the utilisation of the Lower Vistula River, and the particular interest lay in the fact that the tubular pump-turbines, developed especially for the Rance tidal plant, were envisaged for nine stations, covering a stretch of 400 km. from Warsaw to the sea, in which there is a fall of 81 m. If this installation is built, the extraordinary situation will occur at times of the river water flowing backwards from dam to dam, instead of in its natural direction. The paper worked out the economics of the scheme and showed that it would be practicable. We shall await with interest further details.

The papers and discussions showed that there is increased interest in pumped storage, but although some German authors said that a pumped-storage station is usually an economic proposition only if the cost per kilowatt does not exceed 1·3 to 1·4 times the cost per kilowatt of a thermal power station. British contributors to the discussion, and particularly Mr. Clarke, of the Central Electricity Generating Board, thought that the cost would have to be rather less. In the discussion also Dr. Jaeger, of the English Electric Co. Ltd., said that pumped-storage plants were nowadays often considered as partners to nuclear power plants, and he was impressed by the very wide divergence of capital-cost figures for nuclear plants which had emerged from various sources even within the same country. Thus he thought that the economic feasibility of any particular partnership scheme between pumped-storage and nuclear plant could only be evaluated in the light of the circumstances of that scheme.

Other speakers said that very careful examination must be made of the rather too easy assumptions that the energy taken in for pumping was always excess energy. There were many cases in which the cost of energy for pumping might well exceed the cost of the peak-load energy produced.

With regard to reversible machines, it was stated that the lesser costs applicable to the simpler installation of such machines could be offset by a decrease in output and by some operational difficulties. Reversible machines needed complete stoppage of the unit for a reversing operation, while with a separate pump and turbine the change-over could be effected in a matter of a few minutes.

Tidal Power

Tidal power was represented by a single paper on the Passamaquoddy and Cobscook Bay project, close to the frontier between the U.S.A. and Canada. In this paper, Mr. John W. Leslie, of the U.S. Corps of Engineers, said that the Passamaquoddy project was unique for two reasons. It was not only a solution of the problem of capturing energy from the sea, but it was also a joint effort between two nations to develop for their mutual benefit a reliable source of electricity. He said that the topography of this area was particularly suitable for a tidal project, since there were numerous islands situated across the mouths of the bays in that area, so that tidal pools could be created by interconnecting the islands and headlands with a series of tidal dams. Near the mouth of the Bay of Fundy, the tides ranged from 11·3 ft. at minimum neap tide, to 25·7 ft. at maximum spring tide, and averaged 18·1 ft.

The project proposed was a simple two-pool plan. The 100 sq. miles of Passamaquoddy Bay would be controlled by 90 filling gates, and would be used as the high pool, and the 40 sq. miles of Cobscook Bay would be controlled by 70 emptying gates, to act as the low pool. The upper pool would be filled during high tide and the lower pool emptied during low tide. Power would be generated by flow from the high pool to the low pool, through a power house containing 30 fixed-blade turbines each rated at 10,000 kW. The turbines would have a maximum throat diameter of 320 in. owing to the low average head of 11 ft. The capacity of the project would range between 95,000

kW to 345,000 kW and the average annual energy generation would be about 1,843 million kWh.

It was interesting to learn from Mr. Leslie's paper that contrary to the experience in Poland and in France, the bulb-type turbine-generator units were rejected for this scheme, the reasons given that although the power-house structure would cost about $300,000 less per unit than for a conventional scheme, the actual turbines would cost about $900,000 more, partly due to import duties and transportation from France. It was admitted that the bulb-type units were found equal to the best Kaplan turbine considered, measured in terms of energy generated in an average year, but it was said that their use would increase the cost of tidal power. The design was said to be relatively untried, and little was known about maintenance costs. Moreover, the Passamaquoddy scheme was only designed for water flow in one direction, and thus the particular advantages of the bulb-type turbine, with six methods of water flow, could not be utilised. The scheme was designed basically as an auxiliary and not to provide firm power on its own account.

The paper gave details of pumped-storage reservoirs, thermal plants, and run-of-river hydro-electric schemes that might be developed at the same time to provide a partner for the tidal project thus giving it economic feasibility, and it was concluded that a hydro plant to be erected on the Rankin Rapids on the Upper Saint John River in Maine, about 175 miles away, was likely to prove the best partner for tidal power.

In the discussion, the author said that no final decision had yet been made as to whether the project should proceed. From France there was news of the Rance scheme, and here it seems that a change has been made when comparing the project to that originally proposed in 1951. To decrease initial capital expenditure the number of generating units has been reduced from 32 to 24 but the rating of each unit has been raised from 9 MW to 10 MW. All the units are to be situated together and the six sluices of 15×10 m. will not now be divided between the two sides of the river but will be altogether on one side. An earth dam will be built to allow for the possible future installation of additional generating units. It was expected that in the course of the summer final decisions on the Rance project will allow construction work to start. The installed capacity, at 240 MW, will now give an annual production of 567·5 GWh, and —more important—guaranteed power at the time of the system peak of 96·8 MW, whatever the peak time may be, during the 1,200 hours of highest loading in the months of December, January and February.

Spanish engineers said that they had investigated a number of tidal-power projects around the coasts of Spain, but had not reached the conclusion that these would be practical at the present time.

Spanish Experience

On what might be described as the reverse of the buoyant picture presented to the World Power Conference sections that dealt with hydro plant, a paper from Spain gave a frank analysis of the problems of a country in which shortages of power frequently occur. The installed capacity in Spain, according to a paper by six Spanish engineers, has increased fourfold during the last 20 years, and in 1958 exceeded 7 million kVA, 70% of which is hydro capacity. The study of electricity restrictions showed that the chief causes had been delays in construction programmes (partly due to difficulties in obtaining import licences) frequent intense droughts, and rapidly increasing demand. The authors attempt an evaluation of the effect of these restrictions on the consumers and say "limiting our computation to industrial consumption, an average in results obtained by three different methods, we obtain a total of 59,000 million pesetas, equivalent to 14% of the national income and 40% of the industrial income for 1957." These restrictions amounted to the deprivation of the consumers of about 6,900 million kWh.

The construction programmes for Spain are given in the paper and show that in 1968, for example, the total generating-plant capacity required to meet the demand will be 897 MW, of which thermal plant will account for 115 MW, water-power plant 268 MW and nuclear plant 100 MW.

Quattara Depression

An interesting paper, in the section on "Methods of Investigation of Energy Requirements," came from the United Arab Republic, and related to the Egyptian region. After giving details of the Aswan dam proposals, Professor Koshairy and Mr. Nabih gave a summary of the latest state of the famous Quattara depression project. The Quattara depression is a natural hollow in the Libyan desert 70 km. from the Mediterranean coast and about 250 km. from Cairo. The lowest point is 134 m. below sea level, and at sea level the area of the depression is about 19,500 sq. km. The proposal is that by forming a lake at 50 m. below sea level, water from the sea at an average in-flow of 656 cu. m. per sec. would pass along a 10 km. open canal, followed by two 60 km. tunnels, and then would be evaporated. One interesting figure was that the formation of the lake at 50 m. below sea level would take 200 years. The power station would consist of six units of 70,000 h.p. each, giving a capacity of 300 MW. The cost of the scheme would be £256 million, and the paper concludes by saying that the High Dam is likely to suffice for the electrical requirements for the Egyptian Region until about 1985, after which the Quattara scheme will come into the picture. If it should prove necessary for the cultivation and industrialisation of the Western Desert, however, it could be undertaken at any convenient time before then.

Capital Requirements

The theme of the 1960 World Power Conference was "Methods for Solving Power Shortage Problems," and while the engineers can put forward solutions to almost any technical problem of providing power supply on any scale and in any part of the world, there still remains the problem of finding the money to pay for it. Thus the paper by Mr. A. D. Spottswood, of the International Bank for Reconstruction and Development, could be regarded as a key paper in the discussions at Madrid. He first gave some very large figures showing that the estimated cost in 1958 prices of the power facilities of the world in existence in 1958 amounted to the equivalent of $79,000 million with an additional $110,000 million for transmission and distribution facilities. Of the 354 million kW (excluding industry-owned generating facilities) installed in 1958, about 233 million kW were of the thermal type, and about 121 million were hydro plant.

Mr. Spottswood gave these figures as an indication

of the order of magnitude of the world's capital requirements for additional electric power. He laid down the plain truth that whatever the mechanism of financing of new development the money must eventually come either from within the enterprise (of generating electric power), through depreciation charges and retained earnings, or from external sources either private or public, domestic or foreign. He mentioned many countries as having adequate capital markets, but in other countries where expansion of power facilities depended on allotments from Government budgets, "only meagre amounts could generally be made available and in consequence expansion lags, the utilities are unable to keep up with the demand, load curtailment follows and poor service results." He went on to say that "if countries with non-existent or limited capital markets and limited ability to borrow abroad should not depend on Government budgets for their funds for expansion (and in most countries this should be their goal in the reasonably near future), then how is the capital to be obtained? The answer is that a very substantial part of it should be earned by the utilities themselves through adequate charges to the consumers of electricity." He thought that an adequate revenue should cover all operating, maintenance and administrative expenses, taxes, interest and adequate depreciation charges, as well as creating a surplus that could be made available to repay all loans (insofar as the periodic amortisation payments thereon are not covered by depreciation), and in addition to set aside an amount sufficient to cover a reasonable part of the cost of future expansion.

The question was, what was "a reasonable part"? Mr. Spottswood thought that up to 50% of the cost of expansion programmes at least should be financed from internal sources. He chastised those who had set power rates too low, and included among them were many of the large power corporations of the world. "The idea is often expressed, with sincere conviction by many people, that low power rates, even if it is necessary to subsidise them, are required for industrial development. This is simply not so." Figures were given to show that the cost of electricity in industry was only about 1·1% to 1·7% of the cost of output of the industry concerned. "If the cost of electricity is such a small proportion of the cost of production and value of output, it is difficult to support the argument that an increase of 10, 20 or even 30% would seriously affect the cost of industrial production or inhibit its development. The lack of an adequate power supply would, however, deter industrial development."

The paper showed that the World Bank, which is owned by 68 countries of the world, has already loaned the equivalent of $1,460 million for electric power in 29 of these countries. It has enough capital to continue this work, and stands ready to make additional loans for good power projects in its member countries. But the projects proposed must be technically sound and the company or agency must demonstrate that he can maintain a sound financial position and has good management.

These down-to-earth sentiments might have exercised a sobering influence on the engineers who, in the best of good faith, advocated extensive advanced thermal and nuclear power projects at the World Power Conference; but there is no doubt that the hydro-electric engineers hearing this cold financial assessment of the soundness of power projects, need not fear that any of their projects would fail to pass the stringent requirements of financiers for sound economic planning.

Truck and Trailer Field Laboratories

The TESTlab Corporation of 3398 Milwaukee Ave., Chicago 41, Illinois, have on the market two mobile laboratories for testing soils, bituminous compounds, concrete and general materials. They can be transported over relatively rough terrain, so that tests can be carried out on the actual construction site. In the truck type a four-wheel drive is available and power winches can be supplied to increase the general

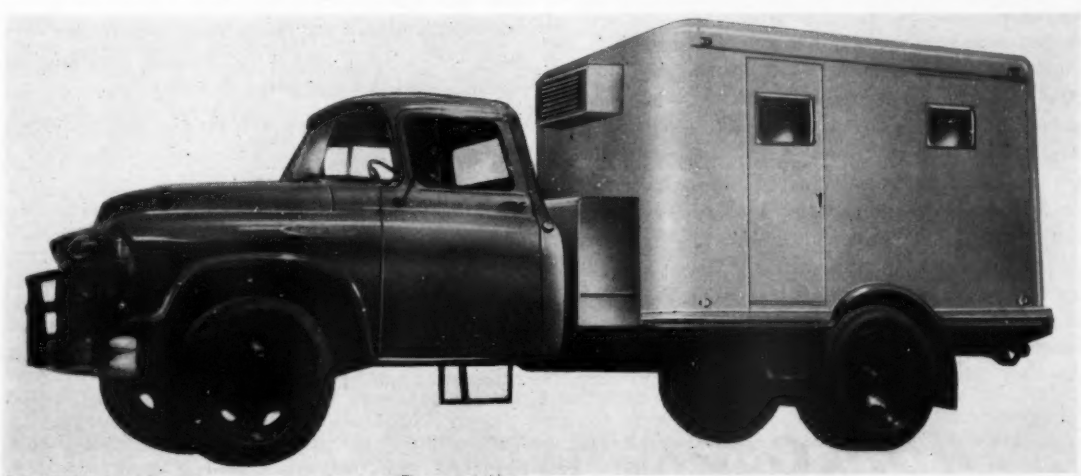


Fig. 1. TESTlab Corporation truck-type field laboratory

THEY USED LIONS ON LUZON

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A few years ago the Agno River in Central Luzon was just another river. Today it is one of the keys to prosperity in the Philippines. A great, six-stage power and irrigation scheme is being carried out along the Agno for the National Power Corporation of the Philippines. When it is completed the mines and light industries of the Cen' al Plain will have a 430,000 kW power supply to draw upon and, for the first time, farmers will be able to cultivate their land during the six dry months of the year.

The first stage of the scheme, Ambuklao, was completed at the end of 1956. Now, the Binga dam - 12 miles downstream - is ready. Built by the Philippines Engineering Syndicate Inc., Binga has a generating capacity of 100,000 kW. Its features include a rockfill dam and chute spillway with six gates; a concrete-lined pressure tunnel leading from the power intake to the turbines in the underground power house; and a concrete-lined tailrace tunnel, 1·2 miles long to carry discharged water from the draft tubes back to the river.

All underground drilling - including excavating two diversion tunnels and two vertical 250 ft. deep shafts as well as the inlet and tailrace tunnels and power house - was carried out with Atlas Copco 'Lion' rock drills fitted with pneumatic pusher legs and Sandvik Coromant drill steels.

Altogether 50 'Lion' rock drills and 8 Atlas Copco 665 c.f.m. skid-mounted compressors and ancillary equipment were used on the Binga project.

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Designed and developed for use together, Atlas Copco rock drills and Sandvik Coromant drill steel equipment form a perfectly balanced team. Currently drilling 1,650,000,000 ft. a year, equal to 41 holes from pole to pole, the combination is today the most widely used in the world.

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Fig. 2. Interior of a typical trailer laboratory

mobility, whereas the trailer type is completely self-contained and is suitable for long-term projects where extreme mobility is not required. In the truck type the van bodies are available in sizes from 10 to 20 ft. long, whereas the trailer bodies are 22 to 50 ft. long and have widths of 8 to 10 ft. These laboratories have proved to be a useful tool for testing and quality control at job sites and are now in use in the United States and other countries. They can be converted to perform almost any kind of research.

Those engaged in surveys or on testing programmes will find that this type of laboratory offers speed, convenience and economy. Every trailer is custom made and all the built-in furniture can be adapted to an almost infinite number of design possibilities. Of interest to most materials testing engineers are an improved Wheeler sieve shaker, controlled humidity cabinets, laboratory ovens, an oven-balance combination, precision direct-reading humidity indicator (hygrometer), several balances and portable field scales. Items of special interest to the soil engineer include a new type of pocket penetrometer for strength tests, an improved type of compaction apparatus, a compression tester, a drilling rig for soil testing and a hydraulically-operated soil-sample ejector. Again, an engineer primarily concerned with cement and concrete testing will be chiefly interested in a high-strength capping compound, a portable electric vibrator, a California sand equivalent set and two models of the Swiss test hammer. A full list of equipment, however, is given in the literature available from the TESTlab Corporation.

To build a more or less permanent laboratory at an actual site, such as a dam, often involves the construction of a building and the setting up of elaborate laboratory equipment, and finally the dismantling of the whole again. The completely equipped mobile laboratory solves most, if not all, of these difficulties. Also this new engineering tool enables a trained technologist to make rapid tests on construction materials at the job site; it is at once versatile and manœuvrable, and, being well insulated, can be used in both hot and cold climates.

Liquid-Zinc Anti-Corrosive Compound

A new liquid-zinc anti-corrosive composition for use on iron and steel and other metal surfaces, has been developed by the MacCleaster Chemical Co. Ltd. (a Powell Duffryn Company), of 8 Great Tower Street, London, E.C.3. The new preparation has a base of chlorinated rubber and zinc dust of extremely small particle size, and among the important advantages claimed for it is freedom from rapid settling out. In the past, the combination of chlorinated rubber and zinc or other metals has created certain problems, one of which has been the rapid settling out of the composition or paint. The MacCleaster preparation requires no more than normal stirring before use.

It can be applied by brush or spraying or by dipping, over rusted surfaces or even over surfaces which have been previously painted, subject only to some scraping or wire brushing. It is also of above average flexibility, abrasion resistant and although not specifically heat resistant, will withstand a dry temperature of 200°C. and a wet temperature of 120°C. It possesses excellent fire retardant properties, prevents "rust creep," is impervious to polluted atmosphere (industrial fall out), to sea and fresh water.

The manufacturers claim that the composition is equally efficient as a single-coat system (as a primer, giving increased adhesive properties to the top decora-

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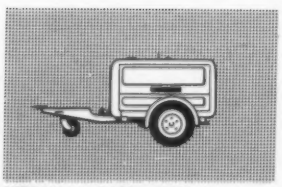
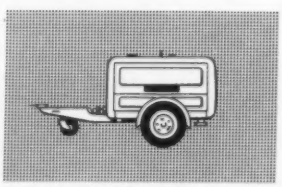
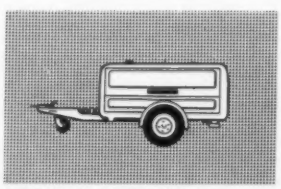


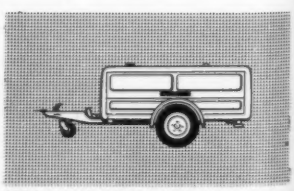
VT3 Weight 2,180 lb (990 kg)
115 c.f.m. (3.2m³/m)



VT4 Weight 2,310 lb (1050 kg)
160 c.f.m. (4.5m³/m)



VT5 Weight 2,900 lb (1315 kg)
225 c.f.m (6.4m³/m)



VT6 Weight 3,590 lb (1630 kg)
315 c.f.m. (8.9m³/m)

PCR1

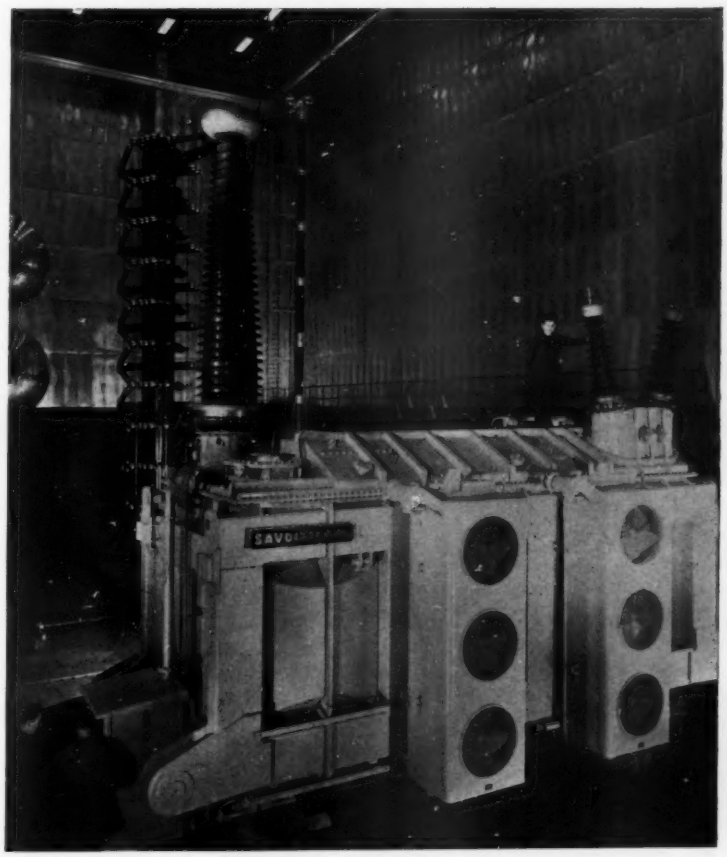
tive finish), making it particularly suitable in the protection of structural steelwork and for general industrial use. Its cathodic properties are especially important for marine application and since the dried film is non-toxic it can be used for the protection of water tanks and cisterns.

Transformers for the World's Highest Line Voltage

The Power Stations Ministry of the U.S.S.R. has placed an order with Savoisienne, Aix-les-Bains, for three three-phase banks of power transformers—two of 270 MVA capacity and one of 300 MVA—for a transmission-line voltage of 525 kV, believed to be the highest system voltage in the world. The order thus comprises nine single-phase units. They are of the three-winding type, for line voltages of 11, 115 and 525 kV, the high-voltage winding being of the autotransformer type. The main windings are of the interleaved type to ensure a linear distribution of steep-fronted voltage surges. Uniform insulation of the windings allows an even temperature rise without the risk of hot spots.

The bank is connected in star on the high-voltage side, the neutral point being directly earthed. The tertiary winding is connected in delta.

An on-load tap-changer of the Jansen type, of 1,800 A capacity, is incorporated and acts directly at the line end of the 115 kV windings. It has a range of $\pm 10\%$ with 11 positions and 10 steps, and short-circuit forces are minimised by the employment of tap-changing windings which do not provoke any unbalanced ampere-turns.



The tank is of the wagon type and is capable of supporting a complete vacuum and an ambient temperature of $-45°C$. For transport it is filled with inert gas, the pressure of which is maintained automatically.

Cooling is by forced oil circulation through four fan-cooled radiators connected to the tank, each provided with a pump capable of starting in oil at $-40°C$.

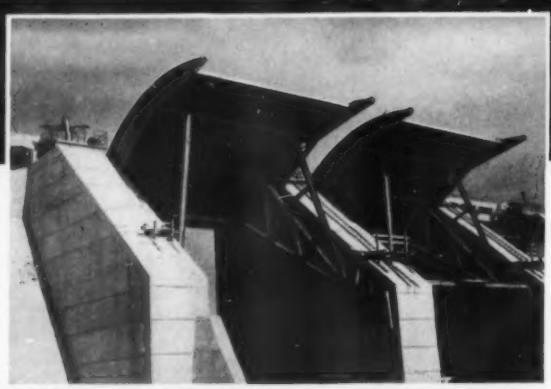
The bushings, constructed by Cables de Lyon, are of the oil-impregnated paper condenser type and are provided with Delle current transformers. The porcelain part of the bushing is in a single piece and is manufactured by Compagnie Générale d'Electro Céramique. The 525 kV bushing has a total length of 6 m., of which 4·3 m. is above the cover and weighs 2·5 tons.

Each of the 90 MVA single-phase units for the 270 MVA banks weighs 175 tons in operating condition, of which 47 tons consists of oil.

Insulation tests, to which the units so far constructed have been successfully subjected, include 50 cycle voltages of 700 and 230 kV at the high-voltage and medium-voltage terminals and 230 kV at the neutral point. Impulse tests comprise 1,500 kV full-wave and 1,800 kV chopped-wave at the high-voltage terminals, 550 kV full-wave at the medium-voltage terminals, and 75 kV full-wave at the low-voltage terminals. Our illustration shows one of the 90 MVA units in the test laboratory at Aix-les-Bains.

Split Rubber Waterstop

Where water pressure exists in concrete structures it is necessary to allow considerable movement at the joints and at the same time prevent water seepage. Tretol-Servicised Limited, 2 Caxton Street, London, S.W.1, now claim an efficient split rubber waterstop of high tensile strength. The split waterstop is supplied with one half of the width divided so that it



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All hydraulic structures (including mechanical and electrical equipment) are supplied and erected ready for operation.

Photos 1 and 2
7 spillway tainter gates 12 x 12 m for dam flood control

Photo 3
Wye pipe for hydraulic power conduit
Inlet opening 7010 mm ø
Outlet opening 4240, pressure 7.6 atm. g
Rate of discharge 17 cu. m/sec

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may be fastened to the inside of the bulkhead so as to form a "T." This eliminates the necessity of slotting and slitting the shuttering. After the section has been formed and the concrete sets, the shuttering is stripped and the two split pieces are stapled together ready for casting into the new concrete, forming the second half of the seal. This simplifies splitform work and hence saves time and costs.

Abstracts from the World Technical Press

Waterproofing the Rock Foundation of Dams

The grouting of dam foundations is discussed and the techniques applied in practice are reviewed. Following a brief introductory note on the specific purpose of the operation, viz., to close fissures, cracks and other voids in the bedrock, the author defines its field of application, and deals with the various kinds of grouting. Separate paragraphs are devoted to grouting pressure, the siting, spacing and direction of borings, selecting the period best suitable for grouting in relation to concreting and other work, grouting technique, and grouting in alluvium. The final section of the article describes the methods actually applied at various dam sites. At Mauvoisin, for example, boreholes aggregating 40,000 m. were injected with 6,000 tons of cement grout. Special galleries had to be driven, particularly in connection with the watertight diaphragm, which extended to a depth of 200 m. below the seat of the dam and to a length of 760 m., lateral sealed zones included. Other examples list the uncommonly awkward conditions which confronted contractors at the Lingese, Rosshaupten, and Castlereagh dams. Two examples of grouting into alluvium are also reviewed: Serre-Ponçon and Sylvenstein. (Dr. Ing. Ferdinand Siemonsen, *Die Wasserwirtschaft*, Vol. 50, No. 1, January 1960, p. 1, 9 pp., 18 ff.)

Developments and Projects in U.S.A.

An interesting account is given of a week's study tour undertaken on the occasion of the 6th International Conference on Large Dams by the representatives of the Italian Ministry of Works and National Research Council. Following a four days' trip to the great Missouri plants from north to south across North Dakota, South Dakota and Nebraska, the party crossed the Rocky Mountains for a short tour of the main works of the Big Thomson project. Short descriptions and the main characteristics are given of the reservoirs, dams and power stations in operation at Garrison, Fort Randall and Gavins Point. Construction work is still in progress at Oahe plant, which has the following main features: (a) a reservoir of 152,000 hectares, 400 km. in length, with a capacity of 29 × 10^9 cu. m., created by a compacted earthfill dam 74 m. high, 2,830 m. long and 1,070 m. wide at the base; (b) a 122 m. long sector-gate-controlled spillweir with eight 7·20 by 15·2 m. sluices designed for a discharge of 8,500 cu. m. per sec.; (c) a power house 595 MW in aggregate capacity, with seven generating sets, of which the first is expected to be on the line in 1962, completion being scheduled for 1964. Of the installations comprised in the Big Thomson scheme are briefly described: the Flatiron plant with its balancing reservoir, the Carter Lake, Estes Lake and Granby Lake reservoirs, as well as the Granby pumping plant, which, in addition to controlling 70% of the waters of the Big Thomson development, constitutes the dispatching centre of the system for all operations of storage and diversion. A paragraph on the Montgomery dam and the reservoir of the same name on the South Platte River, which flows into the Missouri south of Omaha, concludes this article. (Dr. Ing. Arturo de Agazio, *Giornale del Genio Civile*, Vol. 97, No. 11, November 1959, p. 963, 10 pp., 10 ff.)

Chiplima Power Scheme

The Chiplima run-of-river plant, stage II of the Hirakud dam project (WATER POWER, September 1955, p. 356) utilises the tailwater from the Hirakud power station by means of a 16 mile power channel divided into two stretches by a pond acting as balancing reservoir. This paper deals mainly with the civil-engineering features of the scheme, in course of construction since the end of 1956. The first two generating units of the Chiplima plant are scheduled to be on the line by the end of 1960. (M. N. Venkatesan, *Indian Journal of Power and River Valley Development*, Vol. IX, June 1959, p. 39, 8 pp., 8 ff.)

NOTE: The whole of the above issue is devoted to the new power projects in the State of Orissa, proposed under the Third Five-Year Plan.

Excavating the Lipno Machine Hall

A detailed description is given of the excavation work carried out in connection with the underground machine hall of the Lipno plant on the upper Vltava, together with its two inclined pressure shafts, sloping access tunnel, and tailrace tunnel. Work started in the first half of 1953 at El. 726 on the two pressure shafts and reached the level of the horizontal penstocks 166 m. below in the beginning of 1955. The inside diameter of the shafts was 6 m. and mucking was performed by two 5 ton hoists. Water infiltration and the lack of pumps of adequate capacity considerably impeded operations. Both shafts were sunk simultaneously, despite the fact that their axes were only 18 m. apart and the solid core between them did not exceed 12 m. at its narrowest section. The upstream shaft (farther away from the spillway block of the dam) was subsequently equipped with a double-decked cage such as is normally used in mines for evacuating spoil, conveying concrete, and for personnel. In addition to the usual emergency ladderway, this shaft also accommodated dewatering piping, compressed-air supply pipes, and the necessary electric cables. The other shaft was used mainly for material transport (timbering, bracing, etc.) and at times for evacuating excavated material. When the bulk of the rock work in the machine hall had been completed, all transport was transferred to either the access tunnel or the tailrace tunnel, and armouring of the shafts, which extends from the intake to the turbine and consists of steel rings 6 m. long by 4·5 m. diameter, was put in hand. Tunnels leading to the valve chamber and thence to the machine hall were driven when the shafts

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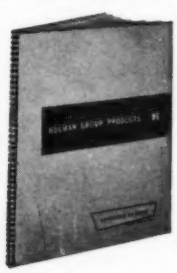

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reached the level of the horizontal supply conduits. The machine hall proper, 66 m. by 21 m. in plan and 39 m. in maximum height was excavated from the top in this manner. When the tunnels leading from the valve chamber had reached the axis of the machine hall, a longitudinal gallery was driven, from either end of which a shaft was led upwards to the level of the ceiling. Furthermore, four narrower shafts were led to the springing of the vault, two on each side, so that the main excavation work could be carried out from several points at the same time. No fewer than 240 men were engaged when excavating was in full swing in three shifts and their output from July to September 1956, though restricted by the inadequate hoisting capacity of the pressure shafts, reached 3,500 to 4,000 cu. m. a month. The walls of the cavern were secured by anchoring as excavating proceeded downwards. From November 1957 onward, when the balancing chamber and the tailrace tunnel had been connected, the rate of mechanisation in tunnelling work in the hall increased, and, with the exception of the 1,000 cu. m., the job was completed by an excavator. Concreting was concluded by October 1958, in no more than nine months, two months ahead of schedule. (Ing. Jan Skalický, *Inženyrské Stavby*, Vol. 7, 1959, No. 10, pp. 382/384, 1 f.)

Syphon Across the Diveria Torrent

To harness the lower course of the Diveria torrent in the Divedro valley (Toce basin), Società Edison are now building the Varzo-Crevola plant, which will have an installed capacity of 47,640 kW and an average yearly output of 175 million kWh. A conspicuous feature of this project is the syphon inserted across the Diveria torrent in the supply system which will convey power water from the Varzo dam intake to the Crevola underground power station. The syphon, together with its upstream and downstream branches, has an aggregate length of 774 m. Its developed length across the torrent is 79 m. and it consists of steel sections 2·80 m. in diameter. (*Quaderni di studi e notizie*, Vol. 16, No. 307, January 16, 1960, p. 1/2 of cover, 1 f.)

Penstock Hooping

The originator of penstock hooping techniques answers in this article to the question: Is it possible in the present state of modern penstock engineering to hoop a pipe without having to resort to self-hooping? The advent of the self-hooping technique has exercised a considerable influence on the manufacture of penstocks. Instead of the simply annealed medium-hard steels used in the old technique of hot hooping, it is now feasible to use for penstock hoops extra-hard steels tempered so as to acquire a high elasticity limit. To meet the new competition, makers of the old style of hot-hooped penstocks were forced to change over to manufacturing processes which were exactly the same as those employed for prestressed hooped penstocks, where the hoops are fitted cold and without any previous machining. It was formerly possible to heat the hoops intended for hot fitting to a very high temperature, when it was fairly easy to fit them on with the required degree of tightness. This is out of the question with heat-treated hoops, which cannot be reheated above the tempering temperature. The variable factor can therefore no longer be the temperature but the hoop diameter, which has to be increased. It thus becomes impossible to arrive at the correct degree of tightness without resorting to prestressing. In fact, this means that modern hooped penstocks, fitted with either cold or preheated hoops, are actually prestressed penstocks. This applies exclusively to rigid hooping and not to flexible hooping by means of jointless rings of wire cable. (G. Ferrand, *La Houille Blanche*, Vol. XIV, No. 6, November 1959, p. 792, 7 pp., 4 ff.)

Macchu Picchu Power Station

A short description is given of the work now in progress in Peru on a loop of the Rio Vilcanota not very far from the famous remains of Inca civilisation. The installations comprise a spillway dam with intake structure, a 3·4 km. diversion tunnel, a surge tank, penstocks, and an underground machine hall. The outdoor transformer station and switchyard, adjacent to the shaft giving access to the machine hall, will be connected with Cuzco by means of a 90 km. 138 kV transmission line. Initially, the machine hall will house two 20 MW generating sets, but later, when a second underground machine hall has been provided, two 40 MW units will be added in two successive stages. Dam, intake works, and diversion tunnel have all been designed, and are being built to operate in conjunction with the ultimate capacity of the plant. The Macchu Picchu project was designed by the Hydro-electric Construction Division of Società Edison, who are acting as consulting engineers. (*Quaderni di studi e notizie*, Vol. 16, No. 306, January 1, 1960, pp. 1/2 of cover, 1 f.)

Substation Equipment

The undermentioned journal devotes three articles to equipment used in substations of hydro-electric power systems: "ČKD Low Oil Content Circuit Breakers," Josef Balon, p. 2, 10 pp., 20 ff.; "Air-blast Circuit Breakers and Isolating Switches," Dipl. Ings. Karel Bárta and Miloslav Vyleta, p. 12, 8 pp., 19 ff.; "ČKD Valve Lightning Arresters," Jiří Myšička, p. 21, 6 pp., 14 ff. (*Czechoslovak Heavy Industry*, English Edition No. 2/1960.)

Tailrace Problems

The Sils power station, now in course of construction, constitutes the downstream stage of the Hinterrhein hydro-electric system (WATER POWER, November 1959, p. 439), and will utilise the turbine discharge of the Sufers-Bärenberg plant, as well as the waters of the catchment comprised between the two stages, and those of the Pignia and Reischen torrents. The discharge of the Sils plant is effected through a 70 m. tailrace discharging into the Albula River 1·5 km. upstream of its confluence with the Hinterrhein. This paper deals with two special problems which confronted the designer when this tailrace was being designed. The Albula diversion establishes a 200 m. straight connection between the inlet and outlet of the loop made by the river around the Albula plant of the Zurich Corporation. This short cut enabled the invert of the tailrace channel to be laid 4 m. deeper than the present Albula bed, the result being a gain of about 7 million kWh a year in production. On the other hand, it became necessary to build a conveniently high spillweir immediately upstream from the confluence of the tailrace with the river. Although both diversion and tailrace are comparatively minor works compared with other hydraulic structures, their

design involved a number of complicated problems which were solved with the help of model tests carried out at Zurich Technical University. With a view to arriving at general solutions applicable to other installations of this kind at the design stage, these tests were supplemented by computations. The two cases instanced established the possibility of using these general solutions in conjunction with other cases such as the determination of the water level downstream and upstream from a confluence, and the determination of the maximum height of surges in a tailrace canal equipped with a regulating gate. (Dr. Ing. Daniel Fischer, *Schweizerische Bauzeitung*, Vol. 78, No. 4, January 28, 1960, p. 52, 4 pp., 4 ff., 5 graphs.)

Prospects of Europe's Electricity Industry

The author of this paper, who is managing director of Società Edison, Milan, gives a general survey of the importance of the various primary sources of energy available in the OEEC countries whose national grids are interconnected, outlines the development of their electric industry between 1948 and 1954, and stresses the significance of international exchanges of energy, not, however, without underlining their limitations. As to prospects for the coming decade, the author forecasts that developments will be influenced above all by the gradual increase of costs in hydro-electric production and their decrease in thermal generation. The financial requirements of construction programmes are then examined, and the author reminds electricity enterprises that the possibility of meeting their requirements depends very much on the extent to which producers will be able to enforce a tariff policy corresponding to the demands of a sound management. The final section of the paper deals with the prospects of nuclear power and reviews in this respect the plans of the interconnected OEEC countries. (G. Valerio, *Quaderni di studi e notizie*, Vol. 15, No. 295, 1959, p. 503, 9 pp.)

NOTE. The above paper is reproduced in French in the *Bulletin de l'Association Suisse des Electriciens*, UCS section, Vol. 51, No. 2, January 30, 1960, p. 77, 8 pp.)

Harnessing the Power Potential of West German Waterways

A comprehensive survey is given of the power potential of West German navigable rivers. The first run-of-river plant on the territory of today's Federal Germany was built on the Neckar in 1891, with an installed capacity of 1,700 h.p. and an average annual production of 2·3 million kWh. Up to 1921, 23 further plants came into service, including no more than two with an installed capacity exceeding slightly 10,000 h.p., the aggregate output being 64,010 h.p. and production about 185 million kWh. The transfer of ownership of all German navigable rivers from the kingdoms and principalities to the Reich in 1921 marked the turning point in the evolution of water power in the country, and from then on planning took a much more rational aspect, extending to multi-purpose developments. By the end of 1958 this development had reached in the aggregate 44% of the harnessable river resources in 85 plants totalling 434,530 kW in installed capacity and 2,387·9 million kWh in yearly production, while there were 64 more plants, either in process of construction or in course of planning. Upon full completion of all these installations, West Germany will have on her navigable rivers a grand total of 149 plants with an installed capacity of nearly 1 million kW and a yearly production of about 5,540 million kWh. The list is headed, as would be expected, by the Danube, from Ulm to the Austrian border (383,500 h.p. and 2,285 million kWh), followed by the Weser (128,000 h.p., 705 million kWh), the Mosel (120,000 h.p., 780 million kWh), and the Main, from Bamberg to its confluence with the Rhine (109,200 h.p., 620 million kWh). The Rhine is not included in this survey. (Emil Renner, *Die Wasserwirtschaft*, Vol. 50, No. 1, January 1960, p. 9, 9 pp., 2 maps, 6 tables.)

Scour Protection below Overfall Weirs

Proceeding from experimental investigations by W. Lehnert in 1952 at the Leichtweiss Institute of the Brunswick Technical University, the author of this paper returns to the idea of substituting a "movable apron" for the traditional stationary apron constructed downstream of weirs for scour prevention. Lehnert's conception consisted first in predetermining the maximum possible scour with an adequate degree of accuracy under the various conditions of flow obtaining at the weir instanced, and then reproducing this theoretically established pattern of scour by means of a protective pitching of stones of sufficiently large size, so as to create a harmless and economic form of energy dissipation. So far, research has failed to determine the exact extent of erosion with the necessary degree of reliability. In his own work the author aimed at formulating a theory of scouring which would pave the way to definitive experimental investigations to establish the technical possibilities of setting up a movable apron of the required design. Owing to the complexity of the problem, his investigations were restricted at the outset to the most important case of the overflow weir. Nevertheless, they extended to no fewer than 600 individual tests, all based exclusively on the assumption of a perfectly aerated overflowing nappe, and the natural pattern of the scour corresponding to each test was subsequently determined. Following a description of the process of erosion, the tests are described and their results analysed. The author claims that his extensive research now makes it possible to apply universally valid functions to any problem which aims at determining the extent of erosion to be expected below an overflow weir for the ultimate purpose of designing the protective movable apron most suitable in pattern and size. Research on the same lines is now to be extended to flow under sluice gates. (Dr. Ing. Wilfried Hartung, Leichtweiss Institute, *Die Wasserwirtschaft*, Vol. 49, No. 12, December 1959, p. 309, 5 pp., 10 ff.)

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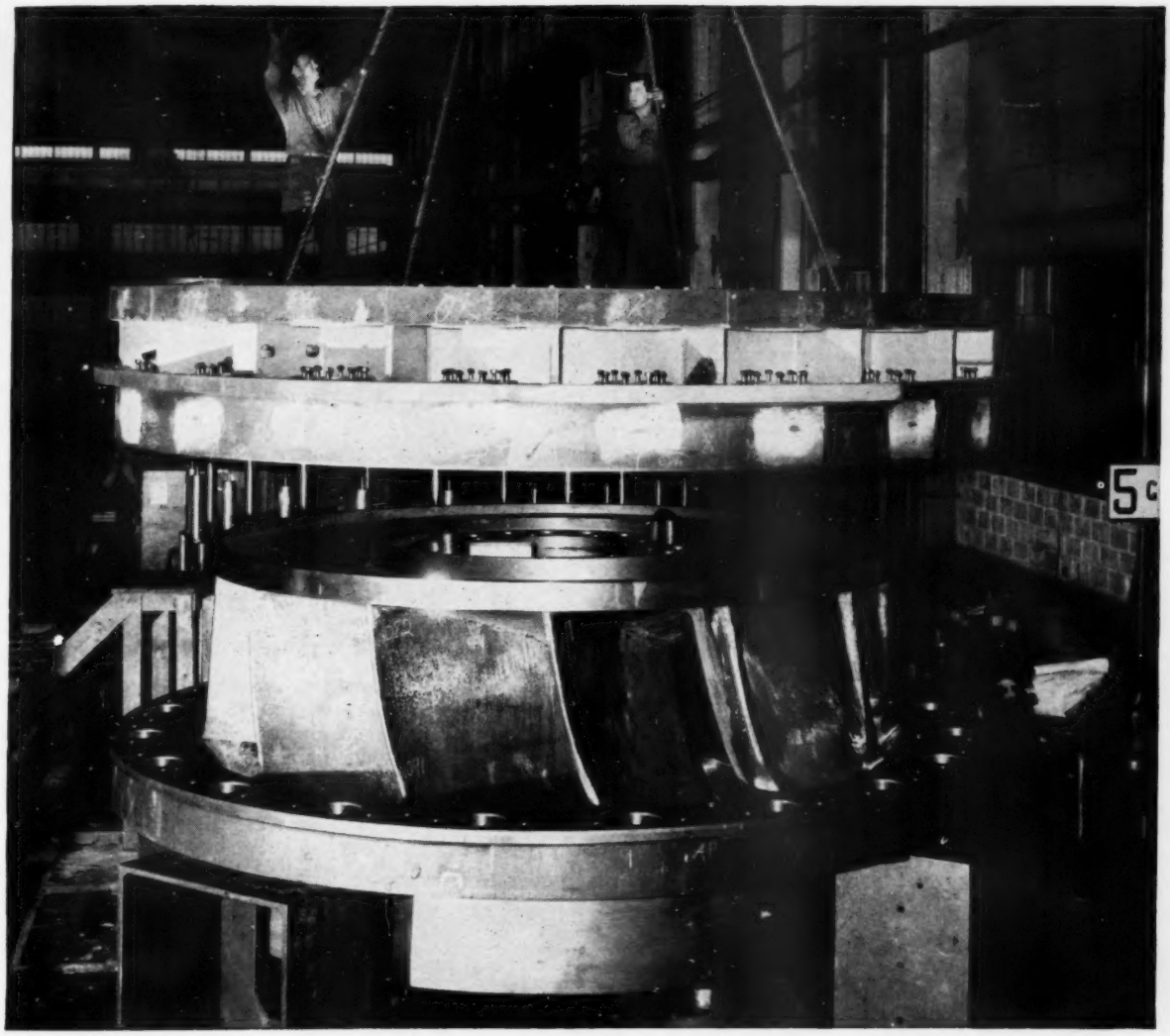

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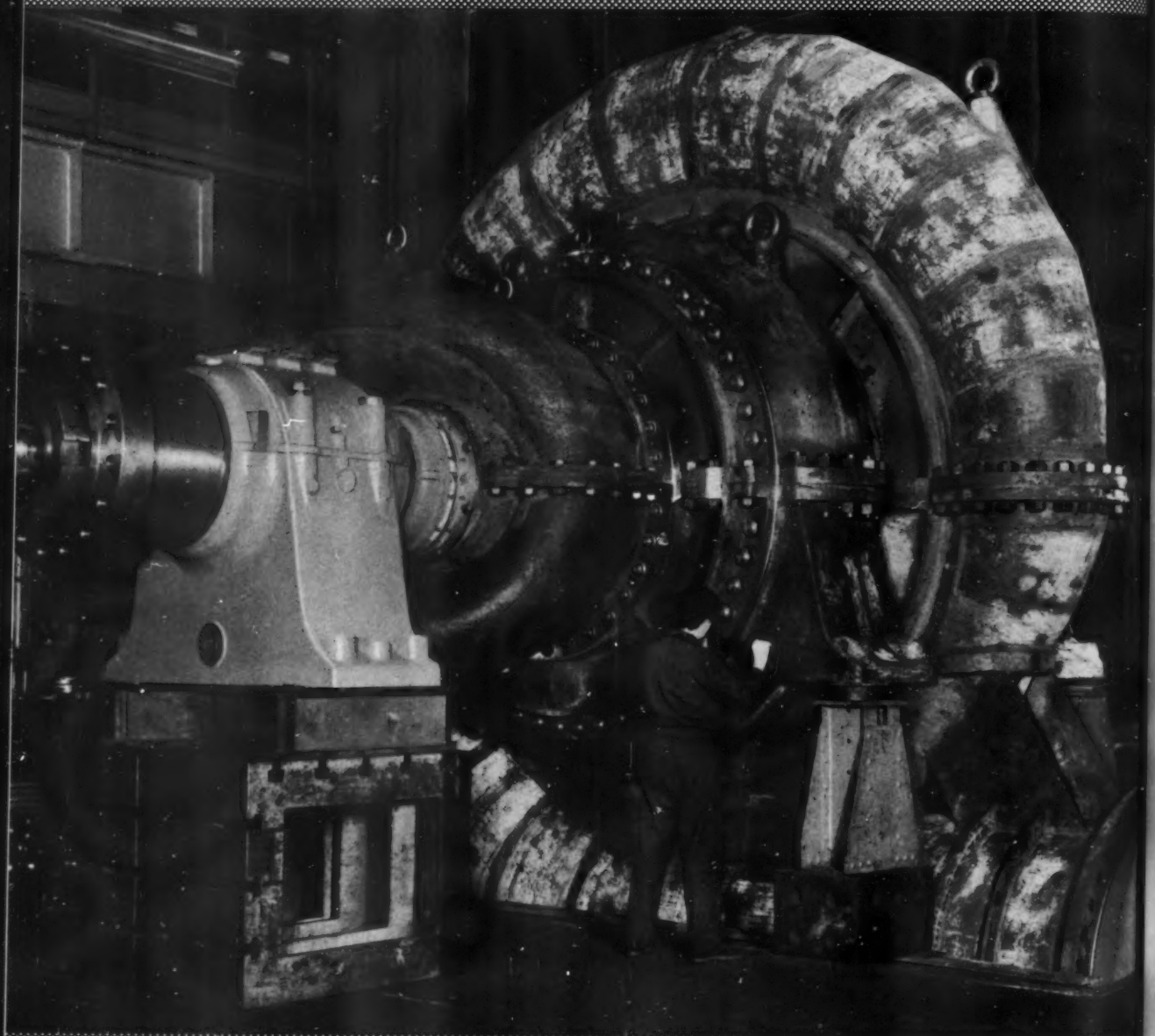

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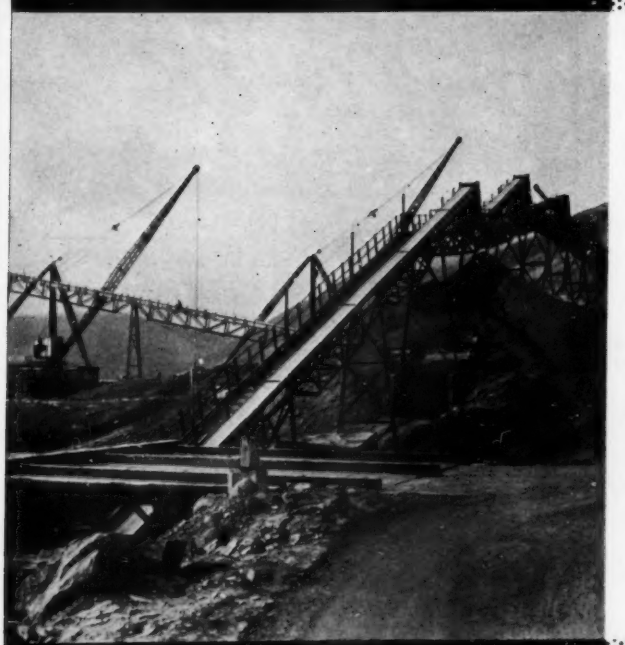

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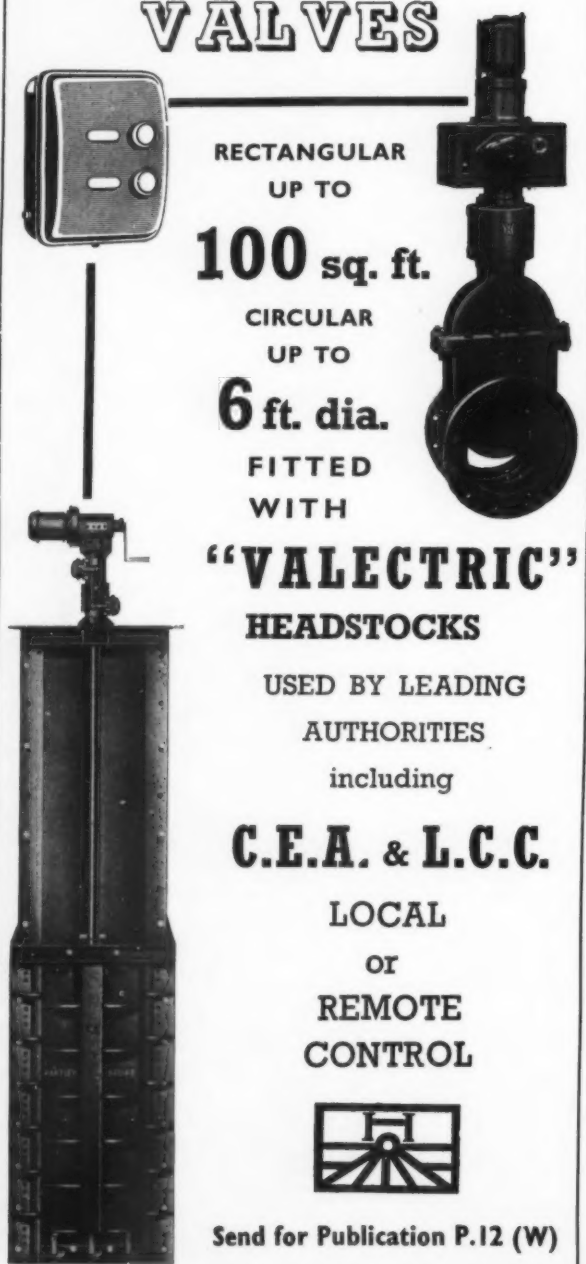

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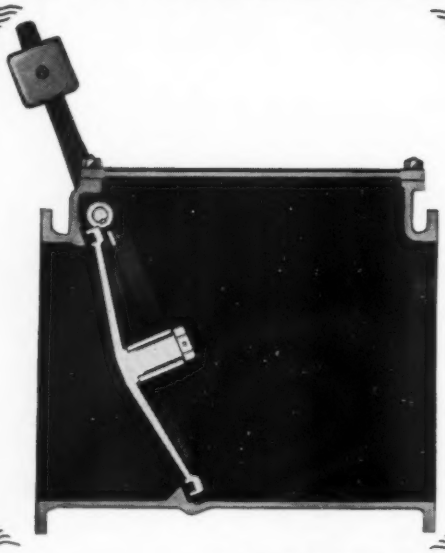

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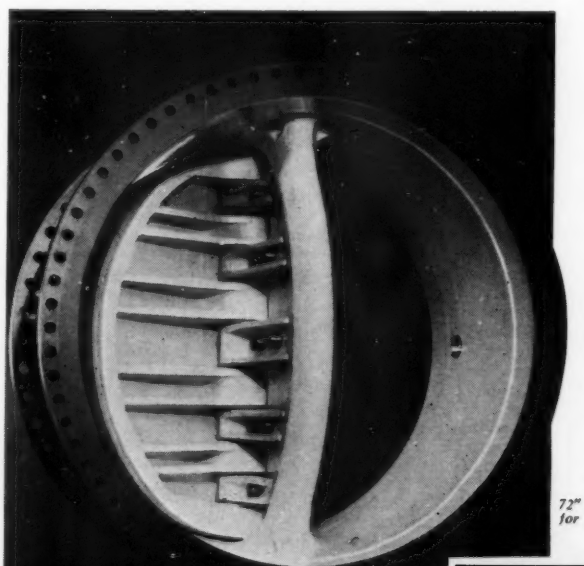

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Y

Yorkshire Electric Transformer Co. Ltd. 12

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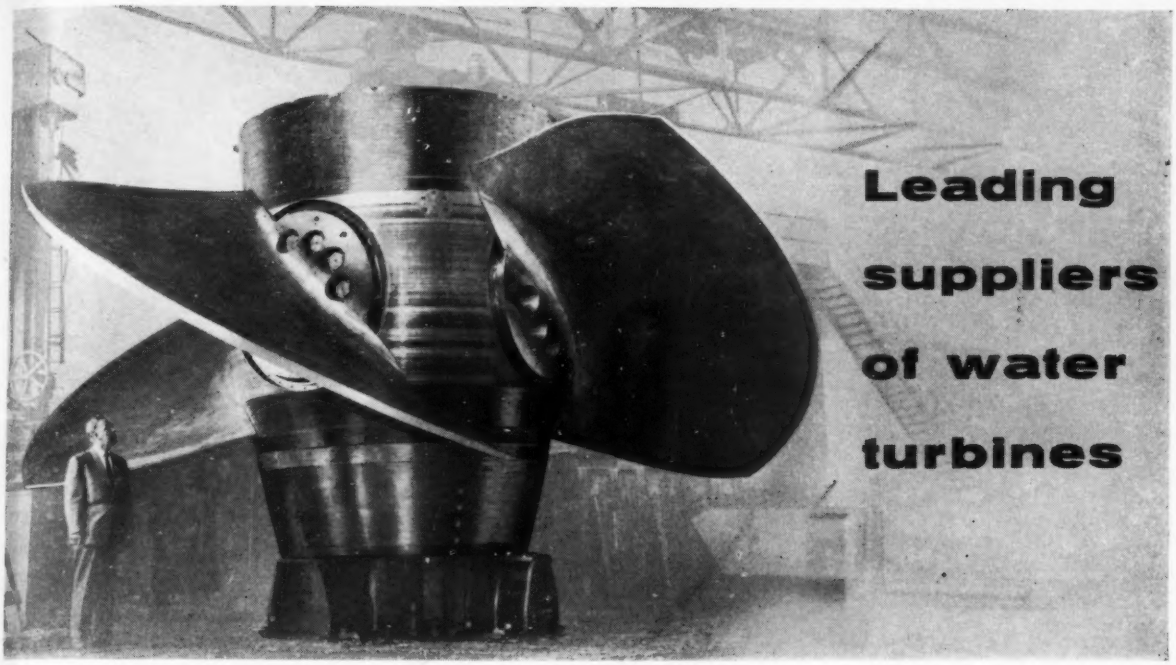

Runner for The Baygorria Power Station, manufactured in NOHAB's shops.

Below is a table of important orders for NOHAB turbines.

Power Station	Number and type of turbine	Head		Output Metric HP per turbine	Speed r.p.m.	Comments
		ft.	m.			
STORNORRFORS Sweden	3 Francis	246-0	75-0	200,000	125	The most powerful water turbines in Europe.
LASELE Sweden	2 Kaplan	170-6	52-0	87,200	150	This is the highest head for which a Kaplan turbine has been installed in Sweden.
PORSI Sweden	2 Kaplan	118-0	33-0	120,200	115	These will be the most powerful Kaplan turbines in Sweden.
MAEL Norway	1 Francis	147-6	45-0	51,000	150	With regard to dimensions, the largest turbine in Norway.
PANCHET HILL India	1 Kaplan	113-0	34-4	80,000	125	India's largest Kaplan turbine in output as well as dimensions.
RINCON DE BAYGORRIA Uruguay	3 Kaplan	48-2	14-7	49,500	79	With regard to dimensions, South America's largest turbines.
FURNAS Brazil	4 Francis	308-4	94-0	230,000	150	Among the world's most powerful turbines

NOHAB

Ample supply of energy in convenient forms is a fundamental condition for the standards of living. NOHAB turbines help to produce electric power in water power plants all over the world.

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Toronto. North Line Road, Toronto, Ontario. Phone: Oxford 9 01 00
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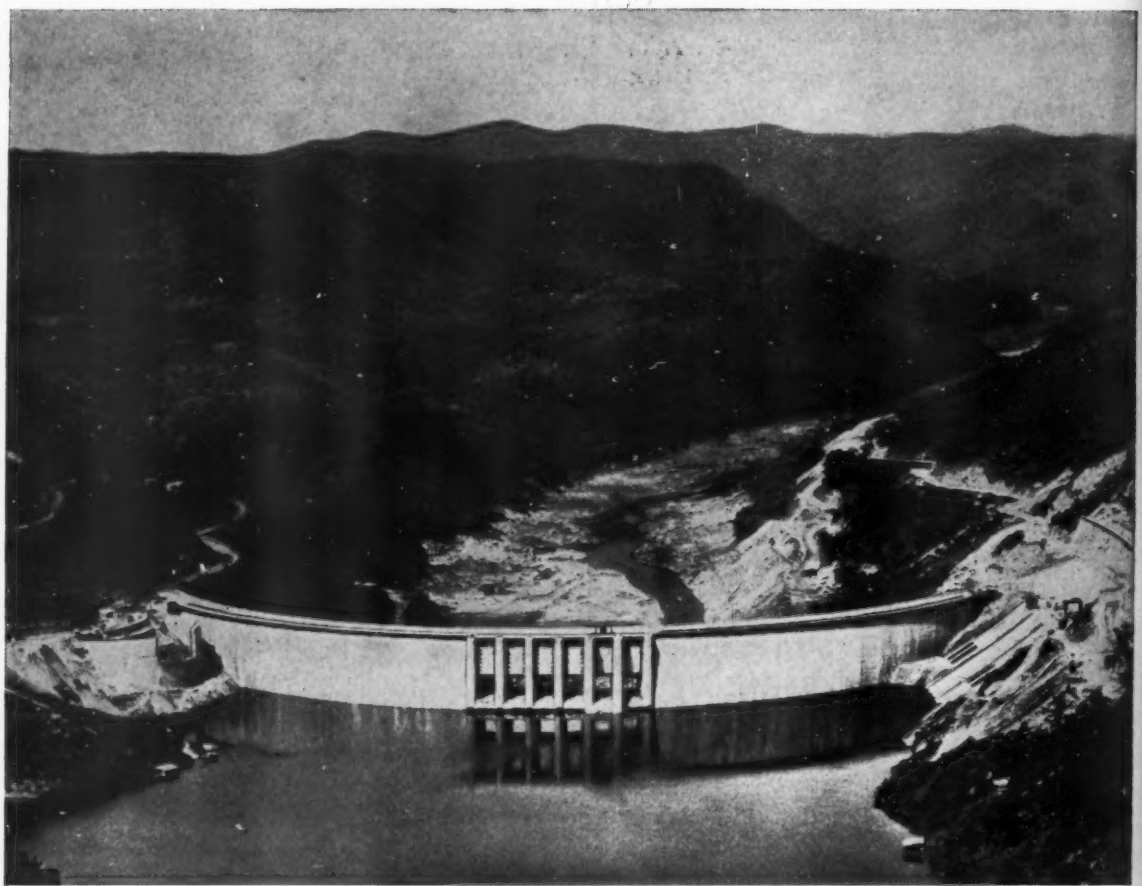

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Six 100-MW generators for Stage One of the massive hydro-electric project at Kariba, on the Zambesi river, are being supplied by AEI. They are the largest hydro-electric generators in the entire continent of Africa.

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